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WILDLIFE RESPONSE TO WHOLE TREE HARVESTING

OF ASPEN: A TEN YEAR ANALYSIS

presented by

Paul Laurent Hamelin

has been accepted towards fulfillment
of the requirements for

Master of Science degree in Wildlife Biology

Jonathan B. Haufler

Major professor

Jonathan B. Haufler

Date 3/25/92

WILDLIFE RESPONSE TO WHOLE TREE HARVESTING OF ASPEN: A TEN YEAR ANALYSIS

By

Paul Laurent Hamelin

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

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ABSTRACT

WILDLIFE RESPONSE TO WHOLE TREE HARVESTING OF ASPEN: A TEN YEAR ANALYSIS

By

Paul Laurent Hamelin

The impacts of whole-tree harvesting on breeding birds and small mammals have been poorly documented, and the harvesting technique may also eliminate potential ruffed grouse drumming logs. The occurrence, density, and diversity of passerines and small mammals, and number of drumming grouse were monitored for 10 years following whole-tree harvesting of aspen. Breeding birds and small mammals were monitored on 3 treatment and 3 control plots pre-treatment in 1981, and post-treatment through 1991. Artificial drumming structures and logs for grouse were placed on the plots post-treatment in 1981.

Vegetative successional changes are discussed relative to these populations. Whole-tree harvesting reduced breeding bird abundance and diversity, but pre-treatment levels were exhibited within 10 years. Bird species-vegetation associations differed among treatment and control plots throughout the study. Small mammal population fluctuations obscured treatment effects. Drumming grouse numbers exhibited an increasing trend during years 5 to 10.

ACKNOWLEDGMENTS

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thanks to Tom Carlson for his support and encouragement of my initial project efforts. I also acknowledge the countless individuals who collected and compiled data for the U.S. Fish and Wildlife Service Breeding Bird Survey.

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INTRODUCTION

New technology in the areas of energy production and wood products manufacturing have created and rapidly expanded markets for aspen (Populus spp.) and other hardwoods of previously limited commercial value. In particular, the whole-tree harvesting method has increased the value and utility of aspen as a merchantable, renewable resource. In the past decade, methods have been developed to allow profitable use of aspen for flakeboard, particleboard, fiberboard, chipboard, plywood, pallets, and furniture, in addition to lumber, veneer, and pulp. The use of aspen for flakeboard has increased fivefold from 1981 to 1989, quadrupling the overall demand from 0.382 to 1.542 million cords in the Lake States during this period (Blythe and Smith 1988, Maass et al. 1990, Youngquist and Spelter 1989). Aspen comprises more than half of the Lake States total pulpwood cut, is used in 85% of all pulp mills in the region, and comprised 35% of the total forest products harvested in northern Michigan in 1979 (Keays 1972, Jakes 1982, Adams and Gephart 1990). Six-hundred-and-twenty-nine-thousand cords of whole tree chips were produced in the Lake States in 1989, and Michigan was the leading producer with

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477 thousand cords (Hackett 1990). In Minnesota, the demand for aspen doubled from 1979 to 1989, and is expected to rise from 1.8 million cords in 1989 to 2.7 million in 1996 (Adams and Gephart 1989). The national domestic consumption and export of pulpwood totaled 88.8 million cords in 1972, and is expected to exceed 178 million cords by 2000 (USDA 1974).

The instability of prices and tenuous supply of fossil fuel has increased interest in wood as an energy source (Keays 1974, Arola and Miyata 1981). Electrical generating facilities in Vermont and Minnesota have proven the reliability of wood chips as fuel. Houghton and Johnson (1976), USDA (1978), and Bradley et al. (1980) evaluated the feasibility and cost effectiveness of wood fuel as a source of energy independence for industries and individuals, and all concluded that it was a viable alternative.

Since its introduction in 1971, the whole-tree harvesting method has gained in popularity. This method uses the entire above-ground biomass of a tree, and usually entails chipping the trees on site, which increases efficiency and decreases transportation costs. Herrick (1982) estimated that chipping increases production by 2.5 times and reduces cost by $6.45 per cord-equivalent compared to conventional pulpwood harvesting. Thus, in addition to increasing the marketability of low grade species and age classes, the technique has become widely used due to its greater efficiency and cost effectiveness, and will continue to be

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to be a favored technique for harvesting aspen.

The total land area of the Lake States covered by the aspen forest type was 5.94 million hectares in 1987 (Youngquist and Spelter 1990). Of the 1.4 million hectares in Michigan, 45% of the trees are more than 60 years old (Raile and Smith 1983). Thus, the current age distribution is heavily skewed to older trees, and is not conducive to sustained yield management. Hammill and Visser (1984) indicated that extensive cutting of aspen will be necessary to meet the objectives of sustained yield and ruffed grouse management in Michigan. These circumstances, combined with the previously discussed increase in demand for aspen throughout the Lake States, may result in substantial whole tree harvesting of aspen in the region in the future.

Although this activity will provide a boom for the forest products industry, its potential environmental impacts have not yet been thoroughly investigated. Several questions have been raised regarding the possibility of erosion, increased leaching, nutrients lost as removed biomass, and the impacts on wildlife populations. Many authors have investigated the first 3 topics, including Aber et al. (1978), Silkworth and Grigal (1982), Pastor and Bockheim (1981), Mroz et al. (1985), and those included in extensive literature reviews by Kimmins (1977) and Van Hook et al. (1982).

The effects of conventional harvesting on wildlife

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habitat and populations have been discussed by many authors. The responses of birds were investigated by Connor and Adkisson (1975), Webb et al. (1977), Crawford et al. (1981a), Back (1982), Horn (1984), Yahner (1987a), Thompson and Fritzell (1990), and Tobalske et al. (1991). Small mammal responses were studied by Morris (1955), Gashwiler (1959), Krull (1970), Kirkland (1977), Ream and Gruell (1980), Buckner and Shure (1985), and Brooks and Healy (1988). Ruffed grouse responses to conventional harvesting of aspen have been discussed by Gullion (1977a, 1984, 1990), and Schulz (1984). However, the effects of whole-tree harvesting on wildlife have not been well documented. Hahn and Michael (1980) investigated the effects of this clearcutting method on small mammal populations and found that 6 years were required for populations to return to pre-harvest abundance. They were not able to demonstrate a relationship between the lack of logging residue and the decrease in small mammals on the clear-cuts.

Eaton (1986) compared the abundance, diversity, and species richness of birds and small mammals on clearcuts harvested by conventional methods and whole-tree harvesting. She found that slash provided 380% more cover on the conventional sites, and that 4 mammal and 9 bird species were significantly correlated with the presence of slash. She demonstrated a dichotomy in which 8 bird species preferred conventional sites and 8 preferred whole-tree harve

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harvested clearcuts immediately following harvest. However, preference diminished and was minimal by the 4th growing season. Similar site preferences evident among small mammals persisted through the 4th growing season.

Small mammals, territorial breeding birds, and ruffed grouse (Bonasa umbellus) are logical choices for studying the impacts of whole-tree harvesting of aspen on wildlife. They have important ecological roles, and songbirds and grouse have aesthetic and economic value as well (Bruns 1959, Johnsgard 1975, Peterson 1980). They often have specific habitat requirements, and thus are sensitive to a gradient of habitat conditions (Hamilton and Cook 1940, Bruns 1959, West 1968, Marks 1974, Graber and Graber 1976, Chew 1978, Maser et al. 1978, Potter 1978, Zagata 1978, Plunkett 1979, Peterson 1980, Ream and Gruell 1980, West et al. 1981, Crawford et al. 1981b, Morrison 1986). Nongame wildlife is gaining more attention from wildlife managers and the public as the aesthetic and ecological values of these species are recognized (Zagata 1978). The maintenance of biological diversity in ecosystems is of increasing concern, and places new emphasis on the importance of nongame species management (Lovejoy 1986, Wilson 1988, Westman 1990).

The emphasis on short rotations possible with the whole-tree harvesting technique (Hammill and Visser 1984, Adams and Gephart 1989) can lead to a reduction in the availab

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availability of snags and slash for wildlife (Navratil et al. 1990). There is also concern that the method might lead to a lack of drumming logs for grouse. Because aspen has the widest distribution of any tree and occurs in at least 27% of the forested acreage on the continent (Gullion 1977b, 1985), there is potential that whole-tree harvesting of aspen may have significant impacts on wildlife throughout North America.

This study was initiated to investigate the response of territorial breeding birds and small mammals to whole-tree harvesting of aspen during the first 10 years following harvest. Treatment effects on abundance, species richness, and species diversity were considered in order to relate population changes to vegetative variables. A pilot study to determine the effectiveness of placement of artificial and natural drumming logs on the treated plots for ruffed grouse was also conducted. Such information is imperative to building a database for sound management of the timber and wildlife resources of the aspen forest type: resources of great economic, aesthetic, and recreational importance to the Lake States region.

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OBJECTIVES

1. To evaluate the impact of even-aged management of aspen by whole-tree harvesting on breeding birds and small mammals:

   a) To describe changes in breeding bird absolute population density, species richness, and diversity during the first 10 years following harvest.

   b) To describe changes in small mammal relative population density, diversity, and species richness.

   c) To describe and relate successional changes in vegetative composition and structure to the trends in breeding bird and small mammal populations.

2. To determine and monitor ruffed grouse drumming activities in clearcuts created by whole-tree harvesting, and in the adjacent forest.

3. To investigate the effectiveness of placement of artificial and natural drumming structures for grouse in whole-tree harvested clearcuts.

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HYPOTHESES

1. Breeding bird and small mammal species composition will change in association with vegetation as succession progresses on the treated plots. Species composition will be distinct to each vegetation type, with some "generalist" species utilizing several types.

2. Breeding bird abundance, species composition, and diversity on the control plots will remain relatively stable throughout the 10 year period.

3. Ruffed grouse drumming activity in the forest adjacent to treated plots will remain stable or increase in response to brood habitat provided by aspen regeneration 4-5 years following treatment.

4. Ruffed grouse will find the artificial and/or natural drumming structures placed on the treated plots to be the only suitable structures on the sites, and will utilize them when aspen regeneration provides suitable cover (5-10 years after treatment).

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STUDY AREA DESCRIPTION

The study area was a 129.5 ha aspen (Populus spp.) stand owned by Dow Corning Corporation, located in the S 1/2 of Section 13, T16N, R2E, Mills Township, Midland County, Michigan (Fig. 1). The area is approximately 7 km north of Midland, 43° 37' N latitude, 84° 15' W longitude.

Located in the east central portion of the lower peninsula, the study site lies within the Saginaw Lake - Border Plain physiographic region (Sommers 1977). Part of the Tittabawassee watershed, the site is drained southeast by the Tittabawassee River, which flows into Saginaw Bay.

In general, the site is poorly drained. Soils consist of the Lenawee, Ingersoll, Pipestone, Wixom, and Kingsville series (Hutchinson 1979). The Lenawee series consists of poorly drained silty clays, and the Ingersoll series are poorly drained silty loams. Pipestone, Wixom, and Kingsville series are poorly drained sandy soils. Topography is gently rolling with slopes ranging from 0-6% (Hutchinson 1979). Thus, depending upon the annual precipitation received (particularly snowfall and spring rainfall), portions of the area may retain standing water almost all year, portions may be inundated through the

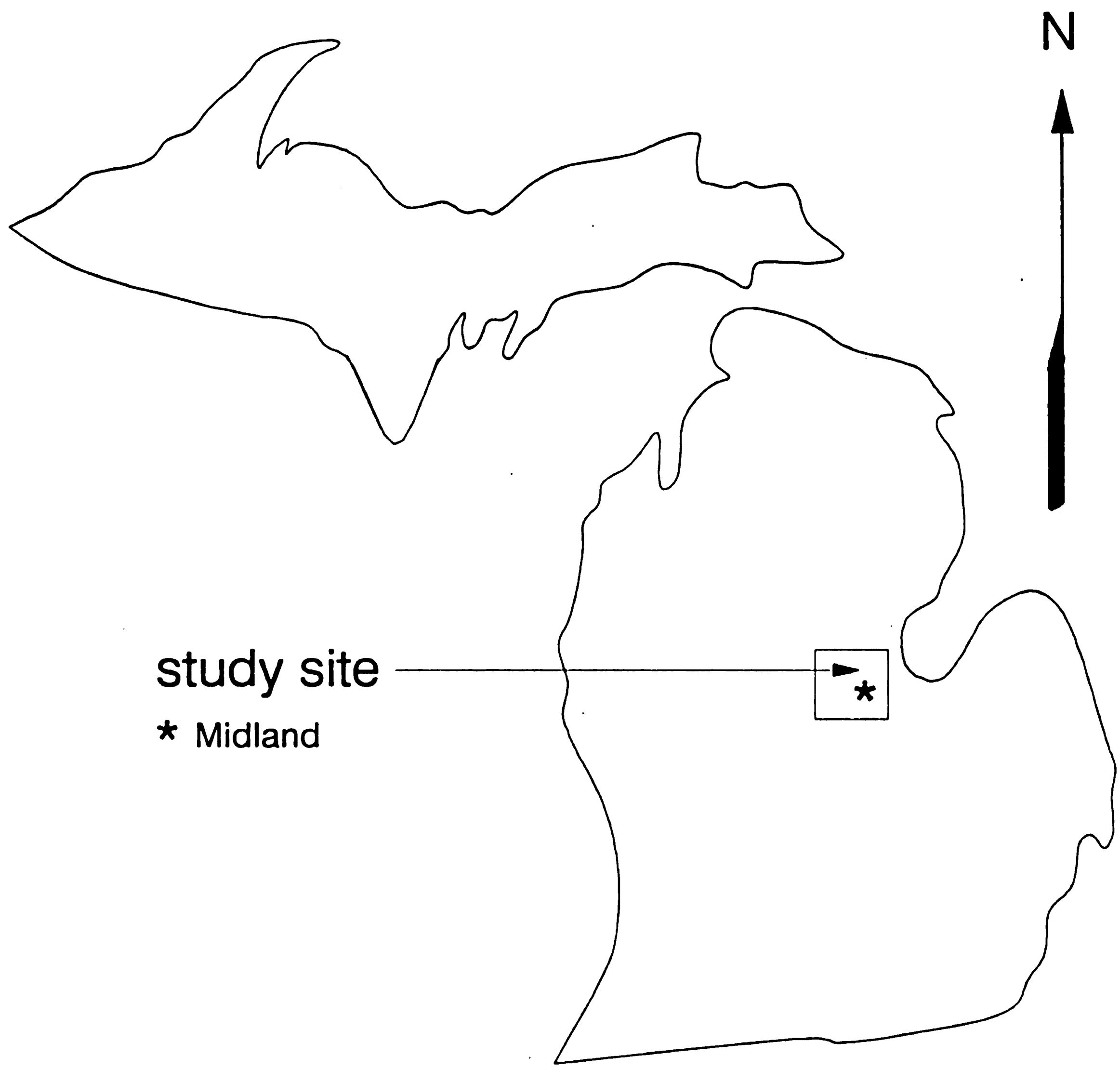

Figure 1. Location of the study site relative to Midland, Midland County, and Michigan.

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spring and summer, and the sandier soils may be wet in the spring and excessively dry in late summer.

The area is shielded from the moderating effects of Lake Michigan by the higher plateau region that lies to the northwest, and thus has a continental-type climate with larger daily, monthly, and annual temperature fluctuations than areas at the same latitude but closer to the Great Lakes (Michigan Weather Service 1974). Mean annual temperature for the area is 8.8°C, ranging from a monthly low in January (-4.9°C) to the monthly high in July (22°C). The mean annual precipitation is 75.2cm, 58% of which is received from May to October. The mean annual snowfall of 92.2cm is approximately half of what is received in the Lake Michigan snowbelt (Michigan Weather Service 1974). Several mean monthly temperatures and monthly precipitation totals differed notably from the long term average during the study period (Table 1) (NOAA 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991).

Prior to harvest in 1981, overstory vegetation consisted primarily of 50-year-old bigtooth aspen (Populus grandidentata) and quaking aspen (P. tremuloides) which were approximately 17-20m in height. Fewer numbers of white birch (Betula papyrifera), swamp white oak (Quercus bicolor), red maple (Acer rubrum), basswood (Tilia americana), and green ash (Fraxinus pennsylvanica) were found on the site. The major understory species were

Table 1. Deviations from monthly mean temperature and precipitation at ...
from 1981 through 1991.

YEAR

Table 1. Deviations from monthly mean temperature and precipitation at Midland, Michigan from 1981 through 1991.

YEAR	TEMPERATURE (°C)				RAINFALL (cm)			
	May	June	July	August	May	June	July	August
1981	-0.14	0.33	-0.05	-0.38	-1.02	1.02	-3.68	4.34
1982	3.02	-2.26	0.19	-1.04	-0.89	5.89	-0.23	-3.43
1983	-2.03	-0.19	1.79	1.65	8.36	-0.89	-3.20	-1.35
1984	-1.46	0.71	-0.57	1.89	4.90	2.39	-3.43	-5.11
1985	1.23	-2.03	-0.28*	-0.75	0.56	0.56	-1.60*	3.45
1986	0.90	-1.42	1.13	-1.04	1.55	-0.30	-2.34	-2.08
1987	1.56	2.03	2.17	0.42	-2.39	-2.64	-4.88	6.22
1988	1.27	1.56	1.98	1.65	-5.28	-5.66	1.88	7.24
1989	-0.52	-0.52	0.94	0.00	8.00	0.48	-5.46	-1.55
1990	-1.37	4.15	0.00	0.28	5.23	-2.92	-1.55	-0.36
1991	2.83	1.89	0.38	NA	4.50	-4.27	5.46	NA

*Data from Mt. Pleasant, Michigan

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bracken fern (*Peteridium aquilinum*), red raspberry (*Rubus strugosa*), blackberry (*Rubus alleghaniensis*), dogwood (*Cornus* spp.), speckled alder (*Alnus rugosa*), and black cherry (*Prunus serotina*). Lesser amounts of viburnum (*Viburnum* spp.), serviceberry (*Amelanchier* spp.), and witch hazel (*Hamamelis virginiana*) occurred in a patchy distribution (Beyer 1983).

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METHODS

Six plots were established on the study area in 1981 (Fig. 2). To insure homogeneity of vegetation among study plots, plot locations and shape were based on the species composition and density of the overstory vegetation. Four rectangular plots, 5.65 ha (201m x 281m) and 2 square plots, 5.81 ha (241m x 241 m) were selected under this constraint. Baseline data on these plots were collected from May through July 1981. Based upon their accessibility, plots 2, 4, and 6 were selected for whole-tree harvesting during the first 2 weeks of August 1981. All vegetation 5cm dbh and greater was cut and chipped, while the majority of vegetation less than 5cm dbh was knocked down by harvesting equipment (Beyer 1983).

VEGETATIVE SAMPLING

Vertical cover was measured by the line intercept method (Canfield 1941) on randomly located transects within each study plot. Three strata were used to measure percent cover for birds on the plots: 0-1m, 1-7m, and greater than 7m. The edge of a measuring tape was used for the line, and vegetation contacts were recorded down to 1cm with gaps in

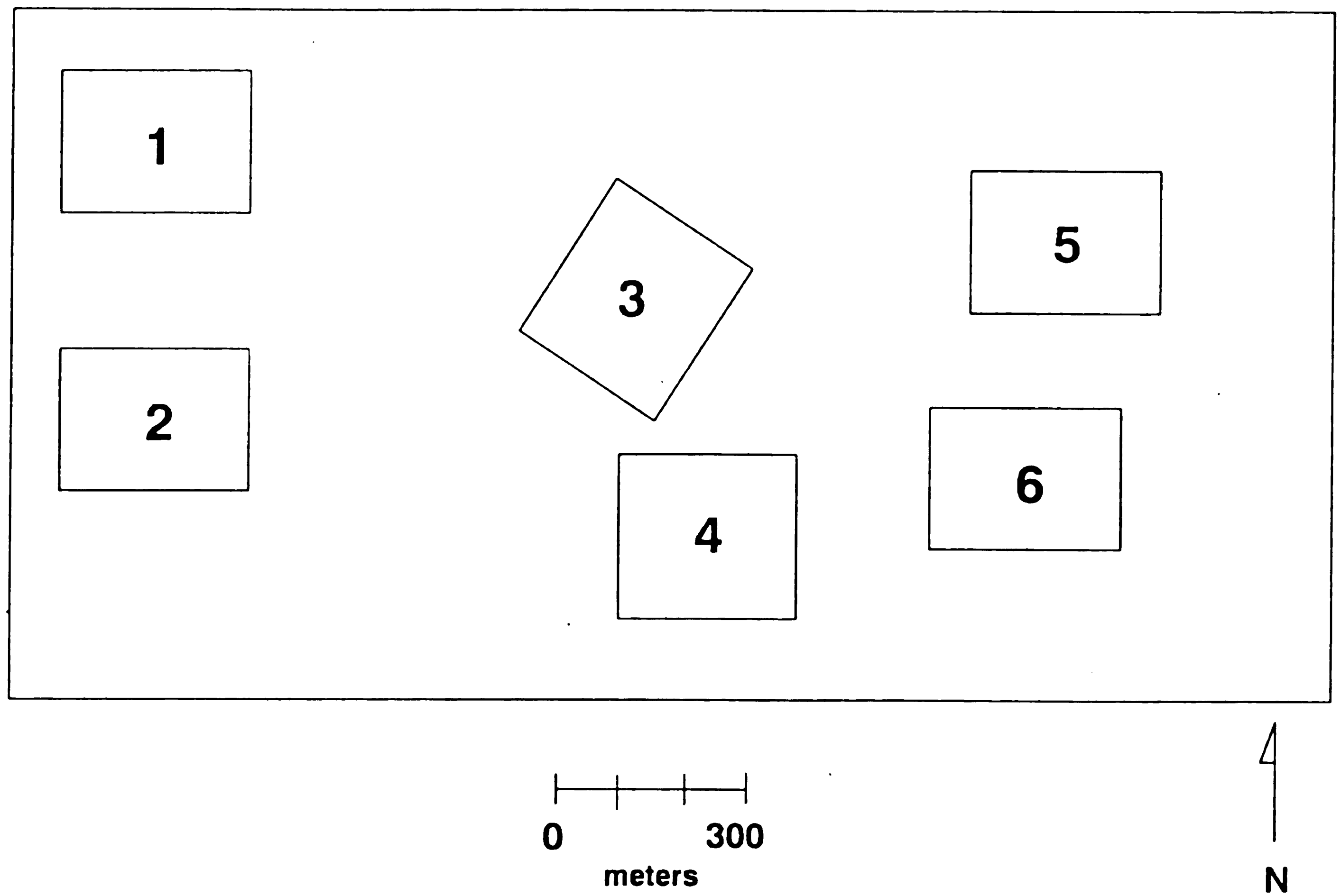

Figure 2. Location of study plots within the study area in Midland County, Michigan.

cover less than 5cm ignored. Number and lengths of transects varied to meet sample size requirements (Beyer 1983).

Nested plots were used to determine density of trees, shrubs, and woody sprouts, and frequency of grasses and forbs. Grasses were recorded by genera, forbs and woody vegetation were recorded by species. For analysis, some woody species were grouped by genera (i.e. "aspen" includes quaking and bigtooth aspen, "elm" includes American and slippery elm, etc.).

Percent cover, frequency of grasses and forbs, and density of woody sprouts and shrubs were sampled on all plots prior to treatment in 1981. In 1981 and 1982, frequency of grasses and forbs was recorded in 2m x 25m quadrats, and woody shrubs and sprouts 5cm dbh and less were counted in 2m x 30m quadrats. In 1982, frequency of grasses and forbs and density of woody sprouts and shrubs were sampled only on treated plots. In May 1982, species and dbh were recorded for all trees greater than 5cm dbh sampled in 10m x 20m quadrats on each of the 3 control plots (Beyer 1983).

From 1986 to 1991, 2m x 5m quadrats were used to sample the frequency of herbaceous species and woody vegetation less than 1m in height. Stems of woody species > 1m in height on the uncut plots were counted in the following size classes: 0-10cm dbh, 10.1-20cm dbh, 20.1-30cm dbh, and > 30cm dbh. Total density of stems > 1m in height was determined for each of the treated plots, with no size classes considered. Densities of both control and treated plots were sampled in 2m x 30m quadrats. Relative frequency and relative density values were calculated for each species (Cox 1976). Vegetation was sampled annually in July or August during this period, and personnel conducting the sampling varied among years.

Statistically adequate sample sizes for all vegetation sampling were determined with Freese's (1978) required sample size formula:

$$n = \frac{s^2 t^2}{E^2}$$

t = tabulated t value at the 90% confidence limit

s = sample standard deviation

E = allowable error (mean multiplied by 20%)

BREEDING BIRD CENSUSING

Breeding bird populations were censused using a spot mapping method (International Bird Census Committee 1970). Censusing was conducted between 15 May and 15 June in 1981, 1982, and 1986 to 1991. Each plot was flagged at 20m intervals to form a grid of reference points for plotting bird species territories. Two observers conducted the censuses each year, and several trial runs were made by both observers together in order to standardize techniques.

Different pairs of observers conducted the censuses in various years. Censusing began 1/2 hour after sunrise and continued for approximately 3 hours. Two study plots were censused each morning. The sequence of plots sampled was alternated to eliminate biases caused by changes in bird activity throughout the 3 hour period. The starting point within each plot was also alternated each census. Censuses were not conducted on days when it was raining, foggy, or when winds exceeded 32 km/hr. Each plot was censused 8 times. International Bird Census Committee (IBCC) guidelines were used for data recording, summarization, and evaluation. An exception to the IBCC guidelines was the size of the study plots, which were less than the recommended minimum size of 10 ha for closed vegetation types (Beyer 1983).

SMALL MAMMAL TRAPPING

Live trapping was used to estimate small mammal populations on all study plots. Trapping was conducted during mid-July and late August in 1981, 1982, and from 1985 to 1991. A 6 x 6 grid with trap spacing of 25m apart was located in the center of each plot. Two Sherman live-traps (H. B. Sherman Co., Tallahassee, FL) (9cm x 9cm x 23cm) were placed at each station and covered with plant material. The traps were placed beside logs and other small mammal travel lanes to maximize captures. Both treated and control plots were trapped concurrently for 5 consecutive nights (Beyer 1983).

Traps were set and baited on the first day of each trapping period and remained set during the 5 day sampling period. The bait mixture used in 1981 consisted of oats, peanut butter, beef fat, raisins, and anise extract. In 1982 peanut butter was deleted and packaged dog food was added to the mixture (Beyer 1983). During the 1985-1991 trapping seasons the bait mixture consisted of oats, lard, and anise extract.

Traps were checked each morning of the trapping period. All newly captured individuals were ear-tagged or toe-clipped. Species, identification number, and location on the grid were recorded for each capture.

RUFFED GROUSE ACTIVITY CENTERS

Ruffed grouse drumming locations were monitored on the 129.5 ha study area during April and May from 1981 through 1991. The site was visited at least 3 times each spring, and drumming counts began at least 1 hour before sunrise and continued through the morning until drumming activity ceased. Grouse were located by approaching a drumming male until the object used as a drumming site was located. Each drumming site was flagged and revisited to verify its use for the majority of the breeding season.

After the 3 treatment areas were cut in August 1981, artificial drumming structures were placed on plots 2 and 4 (Fig. 3). Plot 6 was left as a control. Two types of drumming structures were placed at each location on plots 2 and 4. One structure consisted of two 1.83 m concrete pipes placed together. One pipe was 61 cm in diameter, and the second pipe was 31 cm in diameter. The second structure at each location was a 3.6 m natural log. Drumming structures were placed end to end separated by approximately 2 m. All were placed in an east-west direction in order to standardize any possible effects that log orientation relative to sunrise might have on choice of structures used by drumming grouse. The type of structure on the east side was selected randomly in each case. The density of stems > 1m in height was tallied within 0.01 ha circular plots centered on each structure in 1991.

DATA ANALYSIS

One way analysis of variance ($P < 0.10$) (Steel and Torrie 1980) was used to test for differences in the density of woody sprouts and shrubs, frequency of grasses and forbs, breeding bird abundance, species richness, species diversity, and small mammal abundance, species richness, and species diversity on control, designated treatment, and treated plots in 1981 and 1982 (Beyer 1983). Equality of variance of these data was tested with Snedecor and Cochran's (1967) test, and data with heterogeneous variances

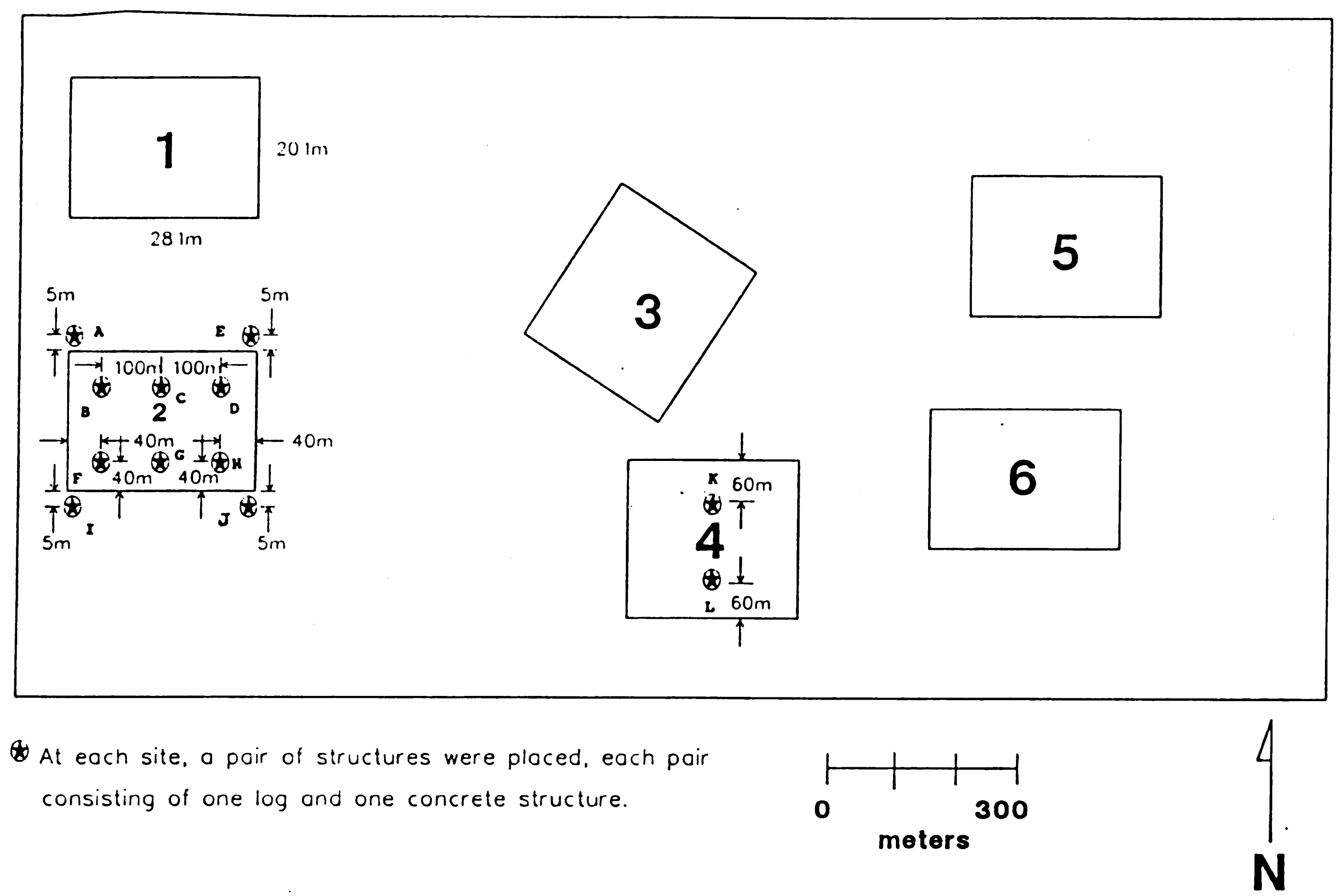

Figure 3. Location of drumming structures in relation to whole tree harvested study plots, Midland County, Michigan.

were transformed by Log (Y + 1) (Steel and Torrie 1980).

Bird species diversity and small mammal species diversity were determined by the Shannon-Weiner diversity index (Ricklefs 1979):

$$H=-\sum_{i=1}^{s} P_i Log P_i$$

P_i = decimal fraction of total individuals or total cover of the ith category

s = total number of strata or categories

Due to erratic, highly variable fluctuations in small mammal numbers among years and months within the same year, standard mark-recapture estimators were not applicable. Kreb's (1966) enumeration technique was chosen as the best relative index to small mammal populations on the study plots:

N = A + P

N = minimum number of individuals of a species alive at time t.

A = actual number of individuals of a species caught at time t.

P = the number of previously marked individuals of a species caught after time t, but not at time t.

The minimum number of individuals of each species alive was determined for each study plot during every trapping period. Absolute population estimates were not essential, as the objective was to determine relative differences between

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treatment and control plots (Beyer 1983). Small mammal species were assigned to 1 of 3 trophic groups based upon food habits: 1) granivore/omnivores (Peromyscus spp., Zapus hudsonius, Napaozapus insignis, Tamias striatus.), 2. insectivores (Balarnia brevicauda, Sorex cinerus), and 3. grazers (Microtus pennsylvanicus). Analysis by trophic groups was feasible only for 1981, 1982, 1986, and 1988 through 1991, as species specific data necessary for trophic group assignment were unavailable in other years.

Spearman rank correlation (Siegel 1956) was used to describe associations between vegetative responses and bird and small mammal responses. Two avian behavior guild types (foraging and nesting) and 5 guilds within each type were selected according to Tobalske et al. (1991). The foraging guilds consisted of (1) foliage foragers, (2) flycatchers, (3) tree drillers, (4) tree (bark) foragers, and (5) ground foragers. Nesting guilds used were (1) hardwood tree nesters, (2) shrub/sapling nesters, (3) primary cavity nesters, (4) secondary cavity nesters, and (5) ground nesters. Each bird species was assigned to both a foraging guild and a nesting guild based upon foraging strategy and nesting behavior information obtained from DeGraaf and Rudis (1983) and Bent (1963a, 1963b, 1968). Individual bird species abundance data were tested for correlations with vegetation responses beginning with the first year in which a species established a territory on one of the study plots.

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RESULTS

VEGETATION CHARACTERISTICS

Vegetation composition and structure were similar on all plots prior to harvest in 1981. There were no significant differences in the density of woody sprouts < 5cm dbh, or in the amount of vertical cover on control and designated treatment plots (P > 0.10) (Beyer 1983). Vegetative species found on the plots are listed in Table A-1.

On the control plots, the amount of cover significantly increased by 53% in the 1m - 7m stratum (P < 0.10) from 1981 to 1982 (Beyer 1983) (Table 2). During the period 1986-1991, cover in the < 1m and > 7m strata generally increased until 1989, then decreased to the minimum value for the study in 1991 (Table 2). During this same period, cover in the 1m - 7m stratum decreased to a minimum in 1991 that was slightly lower than the 1981 value.

On the treated plots, the >7m stratum was completely removed by harvesting, and cover in the 1m - 7m stratum was significantly reduced (P < 0.05) by 86% from 1981 to 1982 (Beyer 1983). Following this sharp decline, cover in the 1m - 7m stratum increased steadily from 1986 to 1990, when it

Table 2. Mean percent cover (standard error) for height strata on control and treated plots in Midland County, Michigan, from 1981-1991.

Table 2. Mean percent cover (standard error) for height strata on control and treated plots in Midland County, Michigan, from 1981-1991.

YEAR	CONTROL				TREATMENT		
	< 1 m	1-7 m	> 7 m	Total	< 1 m	1-7 m	Total
1981	95(5.0)	+53(25.0)	89(11.5)	237(*)	98(2.5)	++72(29.5)	170(*)
1982	97(11.5)	+82(16.7)	81(13.5)	260(*)	98(9.5)	++10(11.0)	108(*)
1986	84.6(0.9)	80.5(2.4)	86.2(0.9)	251.2(3.1)	92.1(2.4)	23.3(2.5)	115.3(4.8)
1987	81.5(5.3)	72.2(7.4)	74.4(1.8)	228.1(*)	97.1(1.7)	34.4(2.0)	131.4(*)
1988	92.9(4.1)	72.9(4.1)	85.7(2.3)	254.8(16.0)	91.6(2.6)	43.4(2.5)	134.9(3.1)
1989	92.7(20.7)	72.2(7.2)	86.1(7.6)	255.9(5.6)	92.3(11.9)	49.8(1.2)	131.4(*)
1990	87.9(3.3)	76.5(6.8)	76.3(7.9)	240.7(16.4)	93.8(2.3)	56.7(7.5)	150.5(9.4)
1991	74.6(1.0)	50.5(13.6)	62.1(9.4)	187.2(22.1)	92.1(2.4)	43.7(5.2)	135.7(7.4)

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again decreased. Mean percent cover in the < 1m stratum was stable, near 95%, throughout the study. Total cover on the treated plots (based on 200%) was positively correlated with total stem density (P < 0.05, r = 0.45).

Significantly higher densities of woody shrubs and sprouts < 5cm dbh (P < 0.05) were found on the treated plots than on controls in 1982 (Beyer 1983). Total stem density generally increased on the treated plots from 1986 to 1991, and remained stable on the control plots during the same period. Mean stem density was 2 to 3 times higher on the treated plots than the controls during 1986 to 1991 (Table 3). Thirteen woody species > 1m in height were found on treated and control plots during 1986-1991 (Table 4 and Table 5).

The density of stems 20cm - 30cm dbh was negatively correlated with percent cover in the < 1m height stratum (P < 0.001, r = -0.70), percent cover > 7m in height (P < 0.10, r = -0.39), and total percent cover (based on 300%) (P < 0.025, r = -0.55) on the control plots. Percent cover < 1m on the control plots was also negatively correlated with the density of stems > 30cm dbh (P < 0.025, r = -0.56).

The absolute and relative densities and frequency distributions of several woody species exhibited trends during the 1986 to 1991 study period. On the control plots, the absolute densities of alder and aspen remained stable in low numbers, as did the relative densities of

Table 3. Mean stem densities (stems/ha) and standard errors ( ) of woody vegetation > 1 m in height.

YEAR	CONTROL					TREATMENT
	0-10 cm	10-20 cm	20-30 cm	> 30 cm	Total	> 1 m
1981	12806(1730)				12806*(1730)	13222*(3560)
1982						16605*(1725)
1986	7179.4(645.5)	329.2(48.3)	185(41.7)	66.7(13.2)	7748.7(686.8)	13229.3(1820.4)
1987	7703.9(875)	287(88)	166.7(33.3)	88.9(21)	8257.8(789.8)	18126.2(1772.7)
1988	6211.2(343.9)	382.2(74.5)	37.8(8.9)	0(0)	6631.2(385.4)	15895.9(2039.6)
1989	5779.6(690.8)	149.6(19.4)	0(0)	0(0)	5928.6(689 0)	14078.1(1817.5)
1990	7978.3(1055.7)	603.7(119.3)	140.7(55.6)	29.3(7.1)	8751.7(1091.1)	24566.6(1915.3)
1991	5349.7(639.2)	369.8(30.16)	144.6(33.3)	13.3(4.6)	5837.0 (607.5)	20677.8(1897.4)

*total stem density < 5 cm dbh

Table 4. Absolute stem densities (stems/ha) and standard errors ( ) of selected woody species > 1 m

Table 4. Absolute stem densities (stems/ha) and standard errors ( ) of selected woody species > 1 m found on the study plots from 1986 through 1991.

	CONTROL					
	1986	1987	1988	1989	1990	1991
Alder	268.7(155.1)	140.4	187.0(95.2)	133.3(67.5)	133.3(67.9)	174.0(122.8)
Ash	2300.7(1064.2)	1899.3	657.3(165.9)	564.7(316.31)	1581.7(383.9)	1248.3(605.1)
Aspen	394.0(154.3)	355.1	305.7(69.6)	130.7(46.4)	392.7(150.4)	326.0(170.6)
Birch	92.00(38.9)	181.7	101.7(54.7)	205.7(9.9)	133.3(50.7)	78.0(40.2)
Cherry	653.3(178.4)	1065.3	607.3(209.9)	371.7(125.2)	374.0(190.3)	362.7(95.2)
Dogwood	161.0(94.0)	1461.6	327.7(186.1)	133.3(117.2)	385.3(231.4)	188.7(114.1)
Elm	546.0(250.0)	512.0	629.3(299.8)	527.0(332.6)	383.9(1248.0)	33.5(40.
Nannyberry	367.7(270.4)	479.0	766.7(705.8)	0.0(0.0)	1248.0(1083.3)	40.4(354.9)
Red maple	728.3(214.7)	594.6	542.7(188.6)	378.7(173.4)	707.7(189.1)	370.3(138.3)
Serviceberry	415.0(115.2)	569.8	287.0(154.2)	657.7(241.9)	422.3(276.5)	500.3(394.1)
Swamp White Oak	867.0(457.7)	602.8	322.0(205.5)	816.5(251.9)	715.0(493.6)	666.7(420.9)
Salix	3.0(3.0)	8.3	3.7(3.7)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Witch Hazel	143.3(106.3)	503.7	229.7(221.2)	605.7(399.2)	326.0(326.0)	203.7(192.8)

Table 4. (Cont'd).

	Treatment					
	1986	1987	1988	1989	1990	1991
Alder	2329.7(386.6)	4132.8	2549.7(702.4)	3355.7(1224.5)	6429.7(997.6)	5381.3(1041.7)
Ash	459.7(346.3)	217.5	291.0(112.0)	313.7(140.9)	855.7(423.2)	585.0(254.6)
Aspen	4452.7(250.0)	5292.9	3416.7(225.5)	1811.3(407.1)	3922.0(293.5)	3640.7(399.0)
Birch	226.7(10.1)	181.3	165.0(57.3)	319.3(171.7)	322.2(192.8)	178.0(73.8)
Cherry	580.3(33.9)	598.16	720.3(238.6)	330.7(70.0)	766.7(83.7)	314.7(38.9)
Dogwood	5113.5(666.7)	3208.3	2665.0(989.7)	4500.9(1312.7)	5715.0(1704.8)	5589.0(1755.7)
Elm	53.3(39.3)	0.0	17.0(6.35)	19.7(12.2)	85.0(57.6)	100.0(54.84)
Nannyberry	915.3(249.2)	525.7	748.0(326.3)	327.7(165.6)	1155.7(580.9)	778.0(331.8)
Red maple	663.3(377.5)	1015.1	779.7(316.2)	1380.3(724.0)	1192.7(596.5)	1170.3(456.5)
Serviceberry	306.7(99.9)	5.4	251.7(96.2)	266.7(192.1)	296.0(124.6)	522.3(327.5)
Swamp White Oak	187.3(32.9)	90.6	131.7(103.9)	125.0(76.4)	155.7(83.2)	148.3(58.2)
Willow	306.7(62.5)	706.9	500.0(56.1)	561.0(225.8)	923.6(215.6)	948.3(141.5)
Witch Hazel	70.3(NA)	54.4	96.4(NA)	189.0(NA)	18.7(NA)	92.7(NA)

Table 5. Relative densities of 13 woody species > 1 m in height found on control and treatment plots from 1986 to 1991.

Table 5. Relative densities of 13 woody species > 1 m in height found on control and treatment plots from 1986 to 1991.

	1986		1987		1988		1989		1990		1991	
SPECIES	Cont.	Treat.	Cont.	Treat.	Cont.	Treat.	Cont.	Treat.	Cont.	Treat.	Cont.	Treat.
Alder	3.9	18.3	1.7	22.8	3.3	19.3	2.1	23.8	1.7	28	3.0	26.0
Ash	27.7	3	23	1.2	11.7	2.2	11	2.2	17.3	3.3	21.4	2.8
Aspen	2.3	35.2	4.3	29.2	5.8	25.8	7.3	20.1	6.5	16.8	5.6	17.6
Birch	0	0	2.2	1	2	2.6	3	2.3	1.6	1.6	1.3	0.8
Brambles	0	0	7.8	3.3	1.8	1.7	5.7	4.1	3.6	0	0	0
Cherry	9	4.6	12.9	3.9	12.5	5.4	7.8	4.8	4.8	3.2	6.2	1.5
Dogwood	1.9	12.6	1.7	17.1	5.8	20.1	2.9	17.8	4.1	22.7	3.2	27.0
Elm	6.6	6.6	6.2	0	11.2	0	8.9	0	10.2	0	11.2	0.4
Nanny-berry	4.4	6.6	5.8	2.9	13.6	5.6	7.1	2.3	11.5	4.5	0.7	3.7
Red maple	10	4.8	7.2	5.6	9.7	5.9	6	9.8	8.4	5	6.3	5.6
Service-berry	5.7	2.2	6.9	0.0	5.1	1.9	9.7	1.9	5.5	1.2	8.6	2.5
Swamp white oak	10.8	0	7.3	0.5	5.7	1	8.2	0	8.3	0	11.4	0.7
Willow	0	2.5	0	3.9	0	3.8	0	4	0	3.8	0	4.5
Witch Hazel	1.8	0	6.1	0.3	4.1	0	8.9	1.3	4.4	0	3.5	0.4

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alder, willow, and dogwood. Some trends in the absolute and relative densities of swamp white oak, ash, white birch, dogwood, and other dominant species were likely obscured by sampling error on both the treatment and control plots. Willow was almost nonexistent on the control plots.

On the treatment plots, the absolute densities of alder and willow increased steadily, as did the relative densities of alder and dogwood. The relative density of aspen decreased, but its absolute density was more erratic. The absolute and relative densities of ash and swamp white oak were stable during the period, as was the relative density of cherry.

In addition to the 14 species in Table 4 and Table 5, basswood, common buckthorn, hawthorne, ironwood, maple leaf viburnum, and red oak were found only on control plots, and spirea was found only on treated plots.

Trends were observed in the absolute and relative frequencies of several woody species < 1m in height. The absolute frequency of bunchberry tended to decrease on the control plots from 1986-1991. The absolute density of bigtooth aspen declined steadily, but quaking aspen remained relatively stable from 1986-1991.

On the treated plots, the absolute frequency of blueberry exhibited an increasing trend throughout the period. Although frequency data for serviceberry < 1m were not collected in 1987, a decreasing trend in the relative frequenc

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frequency of this species on treated plots was evident. In addition to these species, 2 less common species (balsam poplar and white oak) were never found on control plots, and 5 species (apple, beech, burr oak, chinkapin oak, and withe rod) were never found on treated plots. Sampling error probably obscured trends in the frequency occurrence of several other common species, including red maple, bunchberry, brambles, and dogwood, on both treatment and control plots

A total of 88 herbaceous species were identified on the plots during the study. Of these, 15 species were never found on the control plots, and 12 species were not found on the treated plots (Table A-1). Trends were evident for the absolute frequencies of several herbaceous species. The absolute frequencies of Canada mayflower and the lichen/moss category on the treated plots were similar, exhibiting an increase and stabilizing trend from 1986 to 1991. The absolute frequency of grass on the control plots gradually increased and stabilized from 1986 to 1991. As with some woody species, trends in the frequency of occurrence of some common herbaceous species (asters, bracken fern, strawberry) were likely undetected due to sampling error.

BREEDING BIRD POPULATIONS

Eighty-four species of birds were observed on the plots throughout the study (Table A-3). Seventy-six species were

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found on the treatment plots, and 62 were observed on the control plots. Eight species were observed only on control plots (Table A-3), and 20 species were found exclusively on treated plots following treatment. Territories were mapped for 49 of the 84 species observed. Of these, 8 species established territories only on the controls, and 11 species held territories exclusively on the treated plots (Table 6 and Table 7). Sixteen species were categorized as "very uncommon", 6 were considered "habitat generalists", 6 were classified as "mature hardwood specialists", and 4 were considered "open/edge species" (Table 8). Treatment plots consistently had a greater number of territories than control plots from 1986-1991. In general, territories were mapped for 40 to 75 % of the species observed on the plots (Table 9).

On both treatment and control plots, some species established territories exclusively during the early years (1981-82), others only during the "middle" years (1986-89), a third group nested on the plots only in the "later" years (1988-91), and a fourth group used the plots for breeding throughout the period (Table 6 and Table 7). This trend was further evident when species that occurred on the plots, but were excluded from the analysis due to constraints of the spot mapping method, were included (Table A-2). Many of the species established territories when the clearcuts were between 5 and 7 years old (Table 7). When the ecological

Table 6. Mean number of territories/10 ha (standard errors) and chronological distribution for 34 bird species censused on the control plots.

Bird Species	Ecological age (years) of study site							
	50 1981	51 1982	55 1986	56 1987	57 1988	58 1989	59 1990	60 1991
Eastern phoebe	0.6(0.6)	0.6(0.6)						
Golden-winged warbler	0.6(0.6)	1.2(0.6)			0.6(0.6)			
Red-eyed vireo	0.6(0.6)	0.6(0.6)	7.0(0.0)	4.7(1.5)	5.2(1.0)	9.9(2.1)	0.6(0.6)	3.0(0.0)
Mourning warbler	1.8(1.0)	1.2(1.2)	1.8(1.8)	0.6(0.6)	1.2(0.6)	0.6(0.6)		
Northern oriole	2.9(2.1)	2.9(1.5)	4.7(1.5)	1.7(1.8)	4.1(2.1)	2.3(1.2)	1.2(0.6)	
Eastern wood peewee	5.8(0.6)	3.5(1.8)	7.0(1.0)	2.9(1.5)	7.6(0.6)	8.2(0.6)	1.8(1.8)	2.9(2.1)
Great-crested flycatcher	2.3(1.2)	1.8(1.0)	4.0(0.6)	3.5(1.0)	4.7(0.6)	9.3(0.6)	1.2(1.2)	5.2(0.0)
Ovenbird	14.0(1.0)	13.4(2.1)	15.1(2.5)	12.2(3.6)	15.7(0.0)	16.9(0.6)	9.9(1.11)	13.4(3.0)
Rose-breasted grosbeak	6.4(2.5)	6.5(2.1)	2.9(2.1)	1.2(2.1)	6.4(0.6)	5.2(1.8)	2.9(1.6)	5.2(2.0)
Veery	8.7(1.0)	8.7(2.0)	13.4(1.2)	3.5(2.0)	5.8(1.5)	7.0(1.0)	1.8(1.0)	5.2(1.8)
Wood Thrush	1.8(1.8)	0.6(0.6)	4.1(1.5)	0.6(0.6)	4.7(0.6)	4.7(2.1)	1.2(1.2)	4.1(1.5)
House Wren	5.8(1.5)	5.2(2.7)	0.6(0.6)		1.2(0.6)	0.6(0.6)		1.2(1.2)
Least Flycatcher	5.8(5.8)	2.9(1.5)	1.2(1.2)		2.3(1.5)	0.6(0.6)	0.6(0.6)	0.6(0.6)
Brown Creeper		1.2(0.6)						
Red-winged blackbird		0.6(0.6)						
Rufous-sided towhee		1.2(0.6)	1.2(1.2)					
Song sparrow		0.6(0.6)					2.9(1.5)	
Common yellowthroat		0.6(0.6)			0.6(0.6)	0.6(0.6)	1.7(1.5)	
Blue-gray gnatcatcher		0.6(0.6)				2.3(1.2)		
Scarlet tanager		0.6(0.6)		0.6(0.6)	1.8(0.0)	2.3(1.2)		2.9(0.6)
White-breasted nuthatch		0.6(0.6)	1.2(0.6)		1.2(0.6)	3.5(1.0)	1.2(0.6)	2.9(0.6)
Northern waterthrush		0.6(0.6)	2.9(1.5)	0.6(0.6)	3.5(2.0)	5.8(3.5)	2.3(0.6)	3.5(1.0)
American redstart		0.6(0.6)	0.6(0.6)	1.2(0.6)	1.2(0.6)	1.2(1.2)	1.2(0.6)	4.7(1.2)
American robin		2.3(1.5)	2.9(1.5)	2.3(1.2)	1.2(1.2)	3.5(2.0)	2.3(1.2)	4.7(1.5)
* Hairy woodpecker			1.8(0.0)	1.2(0.6)	0.6(0.6)		0.6(0.6)	1.8(1.0)
* Black-capped chickadee				1.2	3.5	9.3	4.1	2.9
Yellow-throated vireo				1.2	1.2	1.2		
* Common flicker					0.6			
Yellow billed cuckoo					0.6			
* Tree swallow					0.6	0.6		
Alder flycatcher						1.2		
Northern cardinal								0.6
Warbling vireo								1.2
annual total # terr.	56.9	58.2	72.1	40.1	75.6	96.5	36.6	64.0

* cavity nesters

Table 7. Mean number of territories/10 ha (standard errors) and chronological distribution for 41 bird species censused on the treatment plots.

Bird species	Ecological age (years) of study site 50 1981	1 1982	5 1986	6 1987	7 1988	8 1989	9 1990	10 1991
* Red-headed woodpecker	0.6(0.6)							
* Common flicker	0.6(0.6)							
Eastern kingbird		1.7(0.6)			0.6(0.6)			
Mourning warbler	1.8(1.8)	0.6(0.6)	5.2(1.8)	2.3(0.6)	1.8(1.0)			
Veery	10.5(2.6)	0.6(0.6)	2.9(1.2)					1.2(1.2)
American robin		0.6(0.6)	1.2(1.2)		1.2(1.2)	3.5(1.0)		1.8(1.0)
* Great-crested flycatcher	2.3(1.6)	0.6(0.6)	3.5(1.0)	1.2(0.6)	0.6(0.6)		0.6(0.6)	2.3(2.0)
Rufous-sided towhee		1.2(1.2)	3.5(1.0)	2.9(0.6)	5.2(0.0)	7.0(1.0)	2.3(1.5)	3.5(2.0)
Gray catbird	0.6(0.6)	1.2(0.6)	5.2(1.0)	8.2(0.6)	8.2(0.6)	8.2(0.6)	3.5(1.8)	10.5(2.0)
Song sparrow	0.6(0.6)	6.4(0.6)	14.5(2.3)	9.3(1.5)	11.1(0.6)	12.2(1.0)	3.5(2.0)	9.3(0.6)
Wood Thrush	2.9(1.5)		2.3(1.5)					
Ovenbird	14.5(1.5)		2.3(2.3)					
Eastern wood peewee	6.4(0.6)		1.8(1.1)					
Red-eyed vireo	0.6(0.6)		1.8(1.0)		0.6(0.6)			
* House wren	7.0(5.2)		4.1(1.6)		3.5(0.0)			1.8(1.0)
Alder flycatcher			2.3(1.2)	5.8(1.0)	2.9(0.6)			
Warbling vireo			2.3(1.5)		0.6(0.6)		0.6(0.6)	
Red-winged blackbird			3.5(2.0)	1.8(0.6)	1.8(1.8)	1.2(1.2)		1.8(1.0)
American redstart			1.8(0.0)	0.6(0.6)	3.5(0.0)	1.2(0.6)		
Field sparrow			0.6(0.6)	0.6(0.6)	1.2(0.6)	5.2(1.0)		
Indigo bunting			4.7(3.0)	1.8(1.8)	7.0(1.0)	1.8(0.0)	0.6(0.6)	
Least flycatcher	1.8(1.0)		6.4(0.6)	1.2(1.2)	3.5(1.8)	1.2(1.2)	2.0(1.2)	
Chestnut-sided warbler			7.6(2.1)	4.7(1.5)	9.9(1.5)	15.7(1.0)	2.3(1.2)	2.3(1.5)
Common yellowthroat			8.7(1.0)	5.8(0.6)	4.0(1.0)	15.0(1.5)	6.4(1.2)	9.9(1.2)
Golden-winged warbler	4.1(1.5)		15.7(3.5)	11.6(2.1)	14.0(1.0)	12.8(1.2)	5.8(3.1)	9.9(1.5)
Northern oriole	5.2(2.0)		6.4(1.2)	5.8(0.6)	5.8(0.6)	2.3(1.2)	1.2(1.2)	2.9(1.5)
Yellow warbler			12.8(0.6)	9.3(2.1)	16.9(2.12)	14.5(1.5)	5.8(0.6)	7.6(2.1)
Rose-breasted grosbeak			5.2(1.0)	4.1(0.6)	9.9(0.6)	9.9(0.6)	5.8(2.8)	4.7(1.2)
Blue-winged warbler			4.0(1.2)	2.3(1.5)	5.8(1.2)	2.3(1.2)		5.2(1.8)
Blue-gray gnatcatcher				0.6(0.6)				
Brown thrasher				0.6(0.6)				
Yellow-billed cuckoo				0.6(0.6)				
White-throated sparrow				0.6(0.6)				0.6(0.6)
Northern cardinal					0.6(0.6)			
Black-billed cuckoo					1.2(0.6)	0.6(0.6)		
* Black-capped chickadee						1.2(0.6)		
Willow flycatcher							1.8(1.0)	2.3(1.0)
Dark-eyed junco								1.8(1.0)
Nashville warbler								1.2(1.2)
* Tree swallow								0.6(0.6)
annual total # terr.	56.9	58.2	72.1	40.1 7	75.6	96.5	38.4	64.0

* cavity nesters

Table 8. Percent species occurrence* and territory occurrence* for 32 bird species in 4 categories found on study plots in Midland County, Michigan, from 1981 through 1991.

Category	% spp. occurrence CONTROL	TREATMENT	% terr. occurrence CONTROL	TREATMENT
VERY UNCOMMON				
Bay breasted warbler	0	5	0	0
Blackburnian warbler	4	0	0	0
Black-throated blue warbler	0	8	0	0
Brown thrasher	0	8	0	13
Connecticut warbler	0	5	5	5
Cooper's hawk	4	0	0	0
Magnolia warbler	0	8	0	0
Northern harrier	0	8	0	0
Olivesided flycatcher	0	8	0	13
Pileated woodpecker	4	0	0	0
Red-headed woodpecker	7	0	0	0
Rusty blackbird	4	0	0	0
Starling	7	8	0	0
Yellow-bellied flycatcher	0	5	0	0
Yellow-breasted chat	4	0	0	0
Tree sparrow	0	5	0	0
HABITAT GENERALISTS				
American robin	100	74	89	75
Bluejay	100	88	non-territorial	
Brown-headed cowbird	89	100	non-territorial	
Great-crested flycatcher	89	89	100	75
Northern Oriole	93	100	89	88
Rose-breasted grosbeak	96	100	100	25
MATURE HARDWOOD SPECIALISTS				
Eastern wood peewee	100	21	100	25
Hairy woodpecker	78	21	67	0
Ovenbird	100	8	100	13
Scarlet tanager	74	17	67	0
White-breasted nuthatch	89	5	79	0
Wood thrush	89	21	100	13
OPEN / EDGE SPECIES				
American goldfinch	11	88	non-territorial	
Blue-winged warbler	7	71	11	63
Gray catbird	22	88	11	88
Yellow warbler	7	79	11	88

* Based on 24 censuses conducted over 8 years

Table 9. Summary statistics for bird populations surveyed on control and treatment plots in Midland County, Michigan, from 1981 through 1991.

Statistic		1981	1982	1986	1987	1988	1989	1990	1991
# spp. w/terr.[a] on both T[b] and C[c]		5	0	2	0	0	0	0	1
# spp. w/terr. on C only		2	17	3	14	12	12	13	13
# spp. w/terr. on T only		4	2	12	18	15	9	9	17
Annual total #spp. observed		44	49	39	55	53	57	58	52
Total # spp. observed	C	35	42	25	26	33	49	32	31
	T	39	31	34	45	44	37	47	36
# spp. w/terr. (spp. richness)	C	13	24	17	18	23	22	17	18
	T	16	8	26	23	25	18	14	20
% of spp. w/terr. of total observed	C	37	57	68	69	70	45	53	58
	T	41	26	76	51	57	49	30	56
Mean # terr./spp.	C	44 (1.1)[d]	2.4 (0.6)	4.4 (1.0)	2.3 (0.7)	3.3 (0.7)	4.4 (0.9)	2.2 (0.5)	3.6 (0.7)
	T	4.0 (1.0)	1.5 (0.7)	5.0 (0.7)	3.5 (0.7)	5.2 (1.0)	6.4 (1.3)	2.9 (0.5)	4.0 (0.8)
Total abundance (mean terr./10 ha)	C	57.6 (3.6)	62.8 (1.8)	72.1 (3.1)	43.0 (1.6)	78.0 (8.1)	101.8 (10.8)	41.3 (5.1)	72.7 (10.9)
	T	63.4 (0.6)	11.6 (0.7)	130.3(15.6)	81.4 (4.1)	130.3 (3.1)	121.0 (1.5)	41.9 (7.0)	86.1 (8.1)
Mean species diversity	C	0.86(0.11)	1.01(0.02)	0.79 (0.04)	0.84 (0.09)	0.98(0.04)	1.08 (0.03)	1.22(0.02)	0.92 (0.14)
	T	1.03(0.02)	1.16(0.05)	1.29 (0.02)	1.30 (0.03)	1.31(0.02)	1.25 (0.01)	1.21 (0.03)	0.99 (0.08)

[a] terr. = territory [b] T = treatment [c] C = control [d]( ) = standard error

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age of the control plots exceeded 54 years, they were utilized for breeding by 5 cavity nesting species: hairy woodpecker, downy woodpecker, northern flicker, black-capped chickadee, and tree swallow (Table 6).

Bird Species - Vegetation Associations

The absolute densities of 6 bird species were negatively correlated with several habitat variables measured during 1986-1991. Great-crested flycatcher and ovenbird abundance was negatively correlated with the density of trees 10-20 cm dbh on the control plots ($P < 0.10$, $r = -0.39$, and $P = 0.01$, $r = -0.62$). Field sparrow abundance was negatively correlated with the absolute density of aspen on the treated sites ($P < 0.10$, $r = -0.48$). The number of red-winged blackbird territories on the treated plots was negatively correlated with cover in the 1-7 m height class ($P < 0.05$, $r = -0.60$). Song sparrow abundance was highly negatively correlated with the absolute density of both alder ($P < 0.001$, $r = -0.87$) and willow ($P < 0.001$, $r = -0.79$) on the treated plots. Yellow warbler abundance on the treated plots was also highly negatively correlated with the absolute density of alder ($P < 0.005$, $r = - 0.70$). No significant correlations were found between weather variables and individual bird species abundance or total abundance. Similarly, no correlations were found between breeding bird population trends on the study sites and

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and population trends for Michigan derived from the U.S. Fish and Wildlife Service Breeding Bird Survey.

Breeding bird species composition and abundance changed concurrent with successional changes in the vegetation on both treatment and control plots. Bird abundance may have also been influenced to a lesser degree by extremes in temperature or precipitation, such as the drought in 1987 and 1988. No significant differences in bird species composition or abundance were found prior to treatment in 1981 ($P > 0.10$) (Beyer 1983). Species richness declined 50% and total abundance dropped 81% on the treated plots in 1982. In 1986, 5 years after treatment, these values had increased by 325% and 1066%, respectively (Table 9). Species richness on the treatment plots exhibited a declining trend from 1986-1990, and a sharp increase in 1991. On the control plots, species richness exhibited a symmetrical increase and decrease during this period. Except in 1982, and the nearly equal values in 1990, total abundance was highest on the treated plots (Table 9). The total number of species observed was highest on the treated plots (mean = 28% more species) for all years except 1982 and 1989 (Table 9). Species richness and abundance on the control plots fluctuated throughout the study. Species richness was lowest in 1981, almost doubled from 1981-1982, and exhibited a nearly symmetrical rise and decline from 1986 through 1991 (Table 9). The total number of species establishing te

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territories was significantly correlated with the total number of territories mapped on the treated plots ($P < 0.025$, $r = 0.82$), but this relationship was not evident on the control plots. The mean annual number of territories per species on treatment and control plots was significantly correlated ($P < 0.025$, $r = 0.79$), indicating that the spot mapping data were interpreted consistently between plots within each year.

Species diversity was higher on the treated sites than controls for every year of the study (Table 9). Diversity on both the treated and control plots increased from 1981 to 1982. In 1986 species diversity was even higher on the treated sites, and at minimum on the control plots. Bird species diversity on the control plots increased steadily from 1986-1990, and dropped in 1991. Diversity remained relatively high on the treated plots during 1986-90, then dropped to its minimum value in 1991 (Table 9).

Avian Guild Trends

Species assigned to each guild are summarized in Table A-4. On both treatment and control plots, species using the foliage foraging strategy were most numerous, followed by ground foragers and then flycatchers (Table 10). Species utilizing the tree drilling and tree gleaning strategies (primarily dependent upon mature trees and snags) were more numerous on control than treatment plots, but low in number on both (Table 10). Species that nest in shrubs and

Table 1[illegible].

Table 10. Number of bird species in foraging and nesting guilds on treatment and control plots in Midland County, Michigan, from 1981-1991.

	1981		1982		1986		1987		1988		1989		1990		1991		Study Total	
GUILD	C[a]	T[b]	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T
Foraging																		
Foligage Forager	5	6	8	1	4	12	6	11	8	14	8	10	4	10	5	11	17	12
Flycatcher	4	3	5	2	4	5	4	4	5	5	6	2	4	3	4	3	8	7
Tree driller	-	1	-	-	1	-	2	-	2	-	-	-	1	-	2	-	2	1
Tree Gleaner	-	-	2	-	1	-	2	-	2	-	2	1	2	-	2	-	3	1
Ground Forager	4	6	9	5	7	9	7	7	6	6	6	5	6	3	5	6	13	8
Nesting																		
Mature Tree	4	4	6	-	5	5	6	3	6	4	7	2	3	3	4	1	6	8
Shrub/Sapling	2	4	6	4	4	11	4	11	5	13	5	10	5	7	5	9	17	9
Primary Cavity	-	2	2	-	2	-	4	-	4	-	2	1	3	-	4	0	3	6
Secondary Cavity	2	2	2	1	2	2	2	1	3	2	3	0	2	1	2	3	3	3
Ground	5	4	8	3	5	8	4	7	5	7	5	5	4	4	3	7	11	8

[a]C = Control
[b]T = Treatment

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saplings were most numerous on the treatment plots, followed by those in the ground nesting guild (Table 10).

On the treated plots, species reductions occurred in all guilds except the shrub/sapling nesting guild in the year following harvest. Conversely, the number of species in all guilds (except cavity nesters, tree drillers and tree gleaners) was substantially higher in 1986, 5 years after treatment, than in 1982 (Table 10).

On the control plots, primary cavity nesting species were twice as numerous as secondary cavity-nesters in the mature aspen (Table 10).

RUFFED GROUSE DRUMMING ACTIVITY

Thirty-eight logs on the 129.5 ha study area were used by grouse for drumming during 1981-1991. One log located on plot 2 (log # 9) and 1 on plot 4 (log # 24) was used prior to treatment in 1981 (Fig. 4, Table A-5). Although these 2 activity centers were destroyed by harvesting in 1981, the number of grouse drumming on the study area remained at 7 in 1982 (Fig. 5). Seventy-nine % of all logs were used fewer than 4 times. Fifty-two % of the logs were used only once (transient logs). Drumming grouse were located on plot 3 in 1983 and 1989, and on plot 5 in 1982, '83, '87, and '90 (Fig. 4, and Table A-5). None of the artificial or natural drumming structures placed on plots 2 and 4 were used, and no grouse drumming was observed on the treated plots. Stem

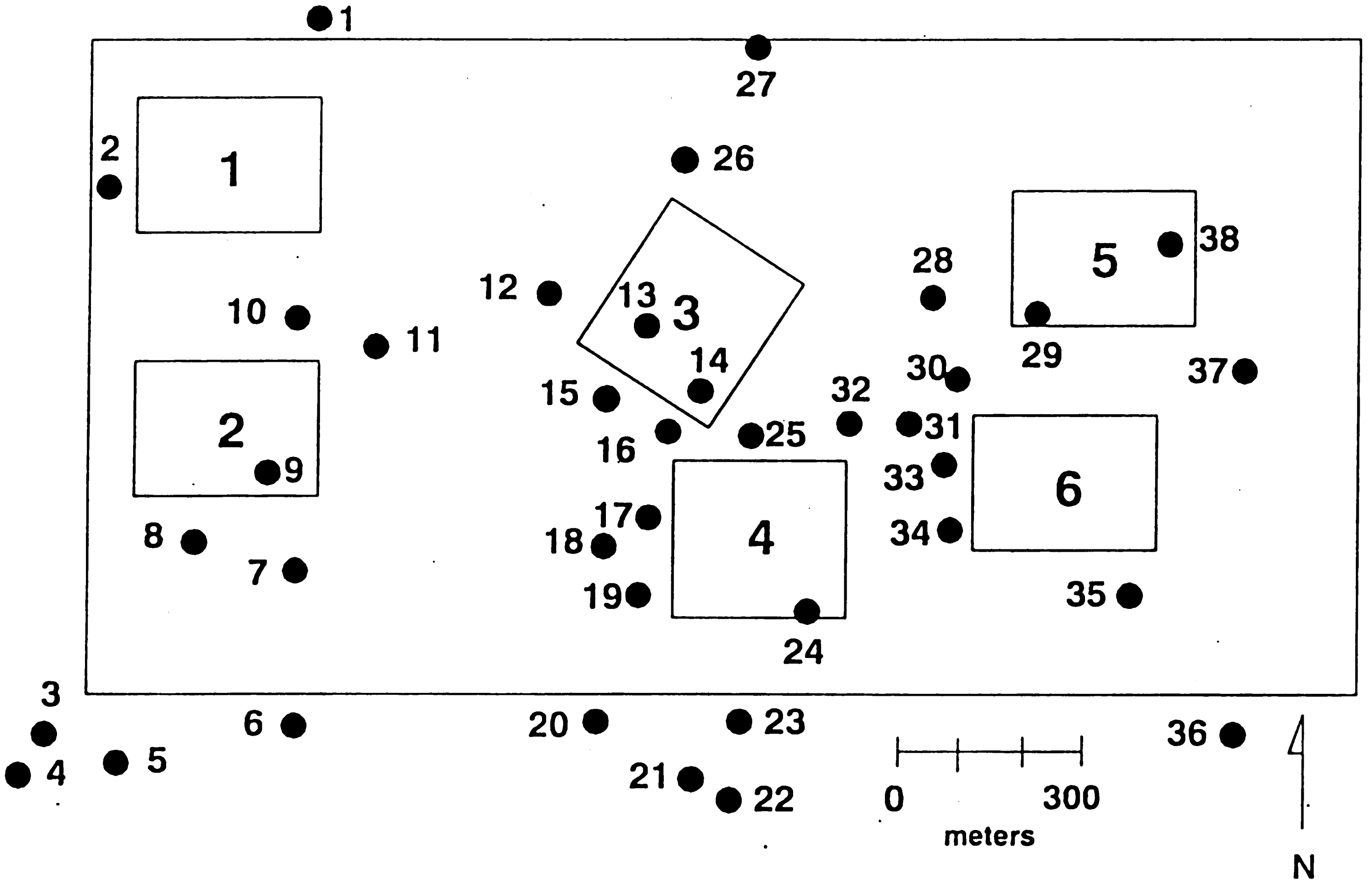

Figure 4   Locations of 38 ruffed grouse drumming logs found on or near the study site from 1981 through 1991.

NUMBER OF DRUMMING GROUSE

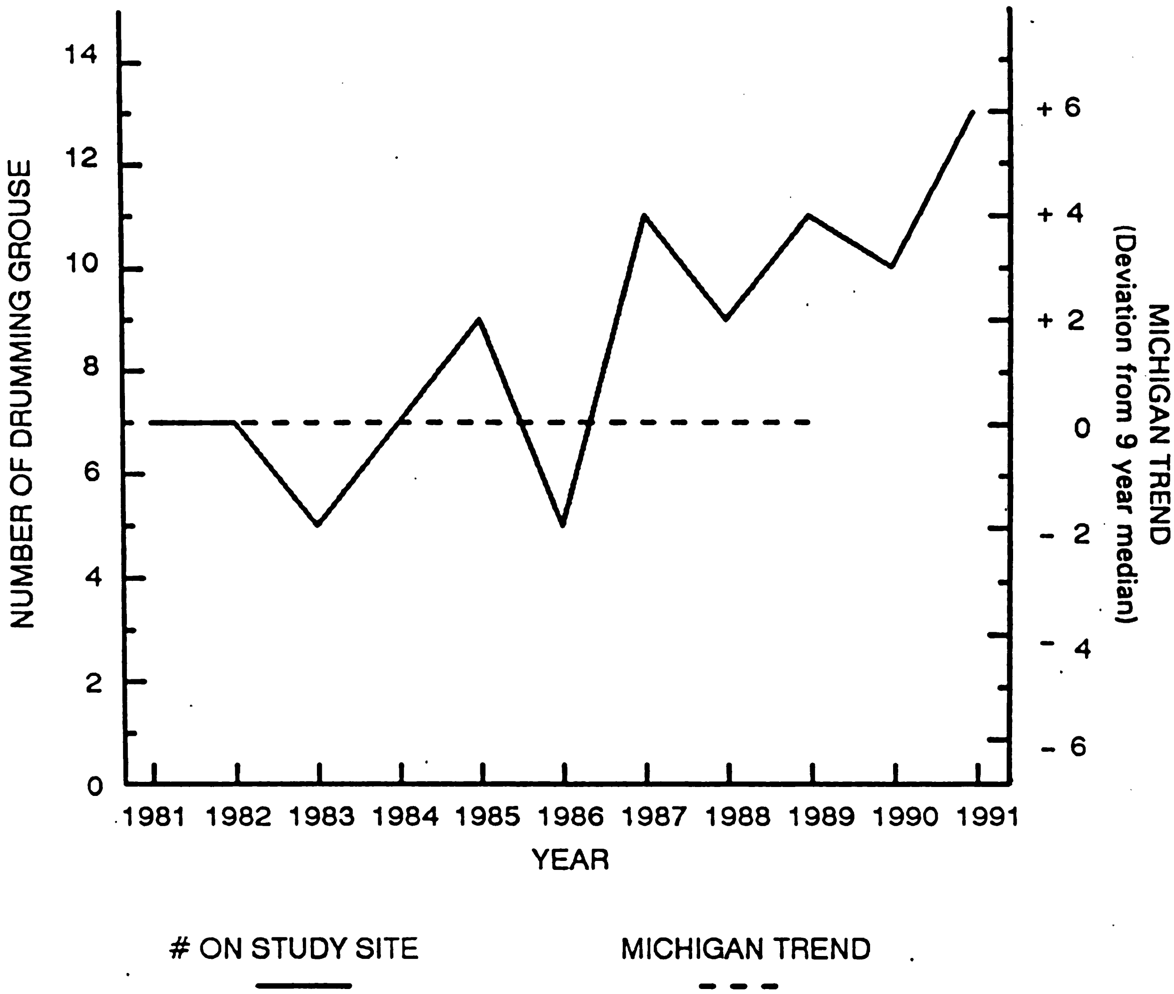

Figure 5. Number of ruffed grouse drumming on the study site (1981-1991) and trend in deviation from the median number of grouse drumming throughout Michigan (1981-1989) based on statewide survey data.

densities around the placed logs 10 years after treatment are summarized in Table 11. Logs at site J could not be relocated, and logs at site C were removed during road improvements in 1984 (Fig. 3).

The number of grouse drumming on the study area was correlated with percent cover in all 3 height strata and the density of stems 0-10 cm dbh on the control plots, and total stem densities on both treatment and control plots (Table 12). The number of grouse drumming on the study site exhibited an increasing trend during the study period, while USDI Fish and Wildlife Service Breeding Bird Survey trend data for Michigan indicated a very slight declining trend (-0.4%) in drumming grouse numbers statewide from 1980 through 1989 (Fig. 5) (USDI 1991).

SMALL MAMMAL POPULATIONS

A total of 13 small mammal species was captured during the study. Of these 13 species, red squirrels (<u>Tamiascuruis hudsonicus</u>), longtail weasels (<u>Mustela frenata</u>), southern flying squirrels (<u>Glaucomys volans</u>), starnose moles (<u>Condylura cristata</u>), cottontail rabbits (<u>Sylvilagus floridanus</u>), and opossums (<u>Didelphis marsupialis</u>) were considered incidental species due to infrequent capture and were thus excluded from the analysis. The species captured in sufficient numbers for statistical analysis were white-footed mice (<u>Peromyscus leucopus</u>), short-tail shrews (<u>Balarnia brevicauda</u>), masked shrews (<u>Sorex cinerus</u>), meadow

Table 11. Mean stem densities (stems/ha) around drumming structures 10 years after treatment, Midland County, Michigan.

LOG LOCATION	NATURAL DRUMMING LOGS Size Class					ARTIFICIAL DRUMMING LOGS Size Class				
	0-10	10-20	20-30	>30	Total	0-10	10-20	20-30	>30	Total
Mature overstory										
A	6100	100	400	0	6600	8200	200	500	0	8700
E	1900	600	300	100	2800	3000	400	200	0	3600
F	10600	300	300	100	11200	10400	700	100	0	11200
MEAN	6200	333	333	67	6867	7200	433	267	0	7833
S.E.	2512	145	33	33	2429	2194	145	120	0	2236
Clearcuts										
B	22700					32800				
D	13600					15700				
G	13600					17300				
H	12000					12200				
I	13100					11600				
K	15700					13500				
L	3700*					2400*				
MEAN	15117*					17183*				
S.E.	1594					3244				

*Logs at location L surrounded by wetland, thus deleted from mean.

Table 12. Correlations between the number of ruffed grouse drumming on the site, percent cover, and stem densities on treatment and control plots, Midland County, Michigan.

PERCENT COVER - CONTROL			
< 1 m	1-7 m	> 7 m	Total
-0.578*	-0.642**	-0.723***	-0.458*

STEM DENSITY		
Control (0-10cm dbh)	Control (Total)	Treatment (Total)
-0.464*	-0.559*	0.615*

* Significant at $P < 0.10$
** Significant at $P < 0.05$
*** Significant at $P < 0.01$

jumping mice (Zapus hudsonius), woodland jumping mice (Napaozapus insignis), meadow voles (Microtus pennsylvanicus), and eastern chipmunks (Tamias striatus). Specimens of the genus Peromyscus positively identified by Beyer (1983) in 1981 and 1982 were all white-footed mice; however, some deer mice (Peromyscus maniculatus) may have been included in the Peromyscus spp. category, as no attempt was made to differentiate these species in subsequent years.

Abundance

Mean small mammal abundance on the control and designated treatment plots was essentially equal in July 1981 (Table 13). Although 36% lower than on the control plots, abundance on the treated plots was not significantly different following treatment in August ($P < 0.10$, Beyer 1983). In 1982 there were greater numbers of mammals on treated plots during both trapping periods, but significantly higher ($P < 0.10$) numbers only in July (Table 13),(Beyer 1983). This was due to a decline (89%) in small mammals (primarily Peromyscus spp.) on the control plots in July, and a concurrent increase in the number of voles and jumping mice on the treated plots in 1982 (Table 14). Small mammal abundance on the treated plots was essentially equal in August 1981 and 1982. By 1985, July abundance on the control plots was equal to the 1981 level, yet conspicuously lower on the treated plots (Table 13). From 1985-1991, July

Table 13. Mean relative abundance values (standard errors) for small mammals trapped from 1981-1991, Midland County, Michigan.

Year	July Control	July Treatment	August Control	August Treatment
1981	47(NA)[a]	46.7(NA)	39(NA)	24.7(NA)
1982	5(NA)	33(NA)	13(NA)	24(NA)
1985	47(1.5)	3.0(1.2)	40.0(0.30)	1.0(0.3)
1986	27.6(6.2)	10.7(2.33)	27(0.59)	33.7(5.7)
1987	5.7(1.8)	1.7(1.2)	21.7(7.40)	23.3(7.4)
1988	15.3(3.7)	9.0(3.79)	14.3(4.38)	10.3(2.34)
1989	7.7(11.5)	7.3(1.73)	22.3(3.18)	16.7(1.86)
1990	27.3(12.8)	26(11.7)	42.3(7.23)	18(4.51)
1991	36(0.0)	30(4.17)	27.0(12.9)	41.3(0.33)

[a](NA) = standard error not available

Table 14. Mean annual species abundance and standard errors ( ) for small mammal species trapped on study plots in July and August from 1981 through 1991, Midland County, Michigan.

YEAR	PERO[a]	STS[b]	WJM[c]	VOLE[d]	CHIP[e]	MASK[f]	MJM[g]	TOTAL
				JULY - CONTROL				
1981	34.3 (NA)	9.3 (NA)	0.33 (NA)	0.0 (NA)	2.0 (NA)	0.0 (NA)	1.0 (NA)	47.0
1982	1.0 (NA)	0.0 (NA)	0.0 (NA)	3.0 (NA)	0.67 (NA)	0.0 (NA)	0.33 (NA)	5.0
1985	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	47.0
1986	20.0 (7.4)	3.3 (0.3)	1.7 (1.2)	0.0 (0.0)	1.7 (0.9)	0.0 (0.0)	0.0 (0.0)	27.6
1987	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	5.7
1988	3.7 (1.2)	0.6 (0.7)	0.0 (0.0)	7.7 (1.9)	3.3 (0.7)	0.0 (0.0)	0.0 (0.0)	15.3
1989	0.7 (0.7)	0.0 (0.0)	NA (NA)	1.7 (0.7)	0.7 (0.7)	0.0 (0.0)	NA NA	7.7
1990	12.3 (8.1)	1.0 (0.0)	11.7 (4.7)	0.3 (0.3)	1.7 (1.7)	0.0 (0.0)	0.3 (0.3)	27.3
1991	15.3 (3.2)	0.3 (0.3)	13.3 (2.2)	0.0 (0.0)	1.3 (1.3)	0.0 (0.0)	5.7 (2.4)	36
				JULY - TREATMENT				
1981	30.7 (NA)	6.7 (NA)	1.0 (NA)	0.7 (NA)	5.3 (NA)	2.0 (NA)	0.3 (NA)	46.7
1982	1.7 (NA)	0.0 (0.0)	0.3 (NA)	22.3 (NA)	0.0 (0.0)	0.0 (0.0)	8.7 (NA)	33
1985	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	3.0
1986	3.3 (0.7)	1.7 (0.3)	0.3 (0.3)	0.0 (0.0)	2.3 (1.2)	1.0 (0.6)	2.0 (1.2)	10.7
1987	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	NA (NA)	1.7
1988	1.7 (0.9)	0.3 (0.3)	0.0 (0.0)	4.3 (2.0)	2.3 (0.0)	0.0 (0.0)	0.3 (0.3)	9.0
1989	2.7 (1.2)	0.6 (0.3)	NA (NA)	3.0 (1.5)	1.0 (1.0)	0.0 (0.0)	NA (NA)	7.3
1990	4.7 (2.6)	0.3 (0.3)	6.0 (3.4)	1.3 (1.3)	1.3 (0.9)	0.0 (0.0)	12.3 (4.3)	26.0
1991	2.3 (0.9)	6.0 (5.0)	3.7 (1.8)	0.0 (0.0)	1.3 (1.3)	0.0 (0.0)	16.7 (2.9)	26.0

TABLE 14 (cont.'d)

YEAR	PERO		STS		WJM		VOLE		CHIP		MASK		MJM		TOTAL
							AUGUST - CONTROL								
1981	28	(NA)	5.7	(NA)	1.0	(NA)	1.0	(NA)	2.0	(NA)	0.3	(NA)	1.0	(NA)	39.0
1982	1.0	(NA)	6.7	(NA)	1.7	(NA)	3.0	(NA)	0.3	(NA)	0.3	(NA)	0.0	(NA)	13.0
1985	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	40.0
1986	13.0	(1.5)	8.0	(1.2)	0.0	(0.0)	0.0	(0.0)	4.0	(0.6)	2.0	(0.6)	0.0	(0.0)	27.0
1987	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	21.7
1988	9.7	(2.7)	0.3	(0.3)	0.0	(0.0)	0.0	(0.0)	4.3	(0.3)	0.0	(0.0)	0.0	(0.0)	14.3
1989	0.7	(0.3)	4.0	(1.0)	NA	(NA)	4.0	(2.0)	1.3	(0.7)	2.3	(1.9)	NA	(NA)	22.3
1990	14.0	(0.0)	9.7	(3.9)	11.3	(3.0)	0.0	(0.0)	2.0	(1.2)	0.3	(0.3)	4.7	(0.9)	42.3
1991	12	(8.2)	1.0	(0.0)	12.0	(4.6)	0.0	(0.0)	1.7	(0.9)	0.0	(0.0)	0.3	(0.3)	27.0
							AUGUST - TREATMENT								
1981	16.3	(NA)	3.3	(NA)	1.0	(NA)	2.0	(NA)	1.0	(NA)	1.0	(NA)	0.0	(NA)	24.7
1982	0.3	(NA)	2.7	(NA)	0.7	(NA)	12.3	(NA)	0.0	(NA)	0.3	(NA)	7.7	(NA)	24.0
1985	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	1.0
1986	3.7	(1.2)	12.0	(4.1)	0.7	(0.7)	0.7	(0.7)	0.7	(0.7)	2.7	(1.2)	12.7	(1.5)	33.7
1987	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	NA	(NA)	23.3
1988	1.7	(1.2)	1.3	(0.9)	2.3	(1.2)	1.3	(0.7)	3.7	(1.3)	0.0	(0.0)	0.0	(0.0)	10.3
1989	3.0	(2.0)	2.7	(0.9)	NA	(NA)	3.3	(1.4)	0.3	(0.3)	0.3	(0.3)	NA	(NA)	16.7
1990	4.0	(2.5)	0.3	(0.3)	2.0	(0.6)	3.0	(1.0)	2.3	(2.3)	0.0	(0.0)	6.0	(0.6)	18.0
1991	4.3	(1.8)	14.0	(4.2)	5.0	(2.5)	0.0	(0.0)	1.7	(0.9)	2.0	(0.0)	13.7	(1.2)	41.3

[a]PERO - *Peromyscus* sp. [b]STS - Short-tailed shrew [e]WJM - Woodland jumping mouse [g]VOLE - Meadow vole
[c]CHIP - Eastern chipmunk [d]MASK - Masked shrew [f]MJM - Meadow jumping mouse
[h]NA - These data not available for individual species.

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mammal abundance on the control plots exhibited a relatively symmetrical decline and recovery, while abundance on the treated plots displayed an unstable increasing trend, never attaining the pre-treatment level. Abundance on the control plots was consistently higher than on treated plots in July during 1985-91.

Small mammal abundance in August 1985 was very similar to July of the same year, with the number of mammals on the control plots greatly exceeding that of the treated plots (Table 14). In August, 1986, the treated plots exhibited a sharp increase (exceeding the pre-treatment level), surpassing the control plot abundance which declined from 1985 (Table 13). During 1986-1991, August mammal abundance exhibited a decrease/increase trend similar to that of July, but neither treatment nor control plots had consistently higher abundance throughout the period (Table 13).

Species Richness

The mean number of small mammal species on control and treated plots was similar in both July and August, and no significant differences were found between 1981 and 1982 ($p < 0.10$) (Beyer 1983). The number of species trapped in 1982 was lower than in 1981 during both trapping periods. The mean number of species trapped during 1985-91 varied considerably between months on both treatment and control plots, with the highest number of species found on treated plots 5 out of 7 years in both July and August (Table 15).

Table 15. Mean number of species per plot (standard errors) for small mammals trapped on treatment and control plots from 1981-1991, in Midland County, Michigan.

YEAR	JULY CONTROL	JULY TREATMENT	AUGUST CONTROL	AUGUST TREATMENT
1981	4.0(NA)[a]	4.7(NA)	5.0(NA)	4.0(NA)
1982	2.4(NA)	3.1(NA)	3.7(NA)	3.1(NA)
1985	3.3(0.33)	2.3(0.88)	2.0(0.0)	1.3(0.33)
1986	3.3(0.33)	4.3(0.88)	4.0(0.0)	5.3(0.33)
1987	2.3(0.33)	1.3(0.9)	4.7(0.33)	4.0(0.6)
1988	3.3(0.33)	3.3(0.88)	2.3(0.33)	4.0(0.58)
1989	3.0(0.0)	3.7(0.33)	5.0(0.59)	5.0(0.58)
1990	4.0(0.0)	4.0(1.16)	4.0(0.58)	5.3(0.33)
1991	3.7(0.33)	4.0(0.58)	5.3(0.33)	5.7(0.33)

[a](NA) = standard error not available

Species Diversity

Small mammal species diversity (Hsmd') was not significantly different ($P < 0.10$) on control and treated plots before or after treatment in 1981. Similarly, no differences were found in 1982 (Beyer 1983). Species diversity on the control plots was equal in July 1981-82, and increased to a maximum in August (Table 16). Diversity on the treated plots was higher than on control plots in July and August in both years, and exhibited a decline during July 1981-82 (Table 16). Small mammal species diversity fluctuated during both trapping periods during 1985-91, but never exceeded the 1981 or 1982 levels in any year. In general, species diversity in August was slightly higher on treated plots during this period, but no similar trend was found in July (Table 16).

Small Mammal - Vegetation Associations

Individual species abundance, species richness, and diversity were correlated with vegetative characteristics only on control plots (Table 17). In addition to these associations, several significant correlations were found between the abundance of woodland jumping mice, meadow jumping mice, and short-tailed shrews and monthly precipitation and temperature data (Table 18).

Table 16. Mean small mammal species diversity (standard errors) for species trapped on treatment and control plots in Midland County, Michigan, from 1981-1991.

YEAR	JULY CONTROL	JULY TREATMENT	AUGUST CONTROL	AUGUST TREATMENT
1981	0.70(NA)[a]	0.95(NA)	0.80(NA)	0.95(NA)
1982	0.70(NA)	0.80(NA)	1.21(NA)	0.90(NA)
1985	0.60(NA)	0.55(NA)	0.31(NA)	0.46(NA)
1986	0.19(0.07)	0.59(0.08)	0.51(0.02)	0.60(0.02)
1987	0.26(NA)	0.15(NA)	0.59(NA)	0.54(NA)
1988	0.48(0.03)	0.44(0.09)	0.31(0.01)	0.51(0.03)
1989	0.32(0.06)[b]	0.50(0.03)[b]	0.57(0.03)[b]	0.58(0.02)[b]
1990	0.42(0.07)	0.45(0.12)	0.45(0.04)	0.64(0.03)
1991	0.46(0.05)	0.45(0.09)	0.62(0.05)	0.61(0.07)

[a](NA) = standard error not available
[b]Didn't differentiate between MJM and WJM in 1988.

Table 17. Correlations (Rs) between small mammal abundance, species diversity, species richness, stem densities in 4 size classes, and percent cover in 3 height strata in Midland County, Michigan.

Correlation Variables	Correlation Coefficient (Rs)
July - Control	
Peromyscus spp. x total small mammal abundance	0.93***
" " X stem density 10-20cm dbh	0.40*
" " X " " 20-30cm dbh	0.85***
" " X " " > 30cm dbh	0.68***
Woodland Jumping Mouse X stem density 10-20cm dbh	0.56**
" " " X % Cover > 7m	-0.63**
" " " X Total small mammal abundance	0.6**
Total abundance X stem density 10-20cm dbh	0.53***
" " X % cover 1-7m	-0.49***
H'smd X stem density > 30cm dbh	-0.40*
August - Control	
Short-tailed Shrew X stem density 0-10cm dbh	0.8***
" " X total stem density	0.79***
Peromyscus spp. X total small mammal abundance	0.67***
Woodland Jumping mice X % cover > 7m	-0.66***
Masked Shrew X stem density > 30cm dbh	0.44*
Total number species X % cover 1-7m	-0.62***
August - Treatment	
Short-tailed Shrew X total small mammal abundance	0.73***
Masked Shrew X total abundance	0.8***
Meadow Jumping Mice X total small mammal abundance	0.85***

* Significant at P<0.10
** Significant at P<0.05
*** Significant at P<0.01

Table 18. Correlations (Rs) between deviations from mean annual monthly temperature and rainfall and small mammal species abundance in July and August, Midland County, Michigan.

Correlation Variables	Correlation Coefficient(Rs)
July - Control	
Woodland Jumping Mice X May rainfall	0.84***
" " " X July temperature	-0.54***
July - Treatment	
Meadow Jumping Mice X May rainfall	0.75***
August - Control	
Short-tailed shrew X August temperature	-0.57***
Woodland Jumping Mice X May rainfall	0.79***
August - Treatment	
Short-tailed shrew X August temperature	-0.74***
Woodland Jumping Mice X June temperature	0.64***
" " " X June rainfall	-0.52**
" " " X August temperature	0.51*
Meadow Jumping Mice X August rainfall	-0.91***

* Significant at P<0.10
** Significant at P<0.05
*** Significant at P<0.01

Small Mammal - Trophic Group Trends

Trophic group responses were nearly identical on treatment and control plots in July, with a few minor exceptions (Fig. 6). Several meadow voles (grazers) were present on the treated plots in 1981, but were absent from the controls. Similarly, insectivores were present on the treated plots and absent from the controls in 1989, and they comprised a greater percentage of the annual total (18% more) in 1991 (Fig. 6).

Trophic group responses were also similar on treatment and control plots in August (Fig. 7). The most obvious shift occurred in 1982, when species in the granivore/omnivore and grazer groups replaced insectivores on the treated plots. Grazers also comprised 15-20% of the monthly total in 1988 and 1990 on the treated plots, but were completely absent on the controls. Insectivores were more numerous on the treated plots in 1991, where they comprised 38.7% of the annual total abundance, compared to 3.7% on the controls (Fig. 7).

Differences among trophic group responses were greater *between months* on the *same individual plots* than between treatments on different plots, with the greatest differences exhibited on the control plots. Insectivores were absent in July 1982, while they comprised the greatest proportion of the monthly total in August (Fig. 6 and Fig. 7). An extreme

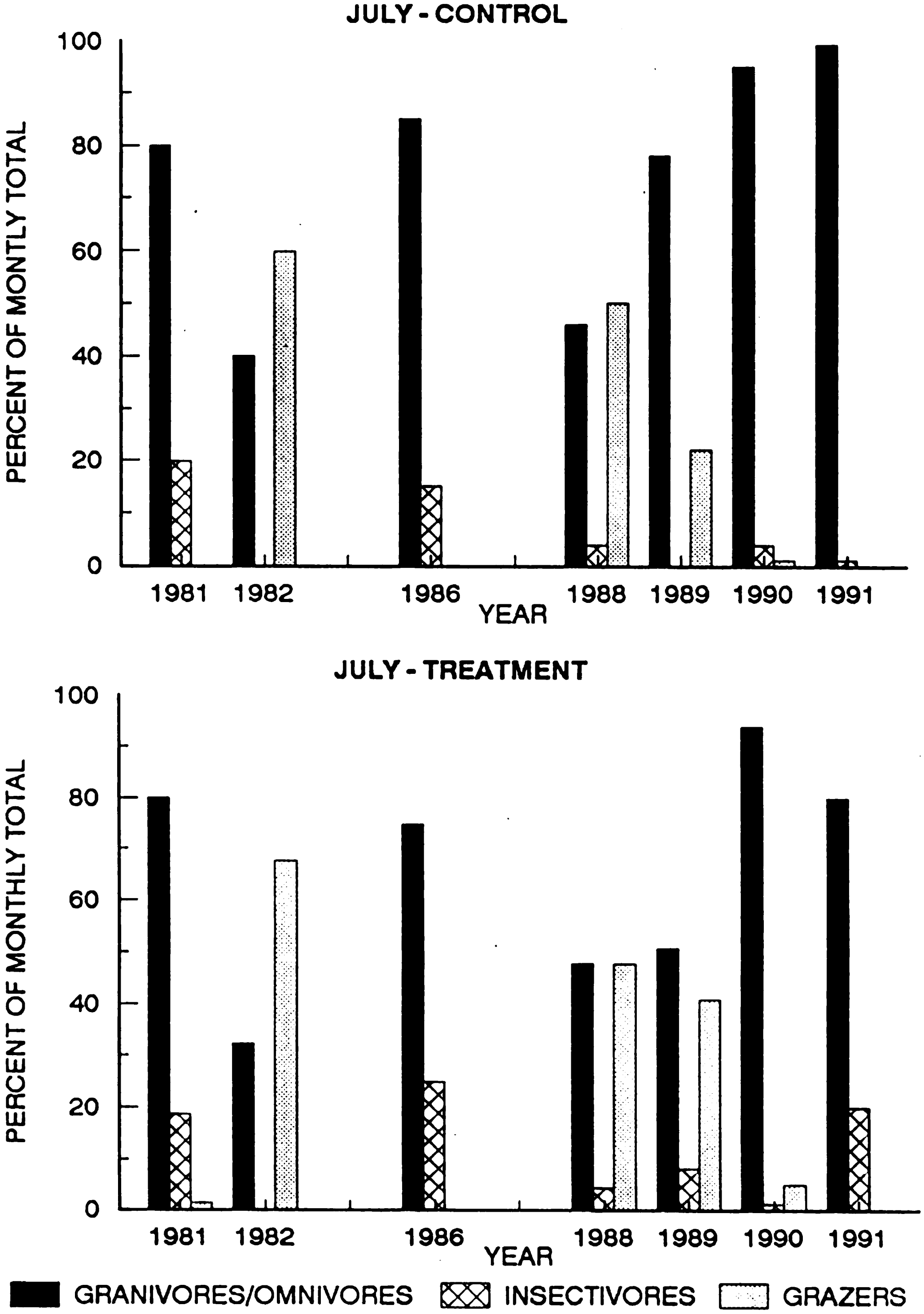

Figure 6. Percent of monthly total number of individuals trapped occurring in each of 3 trophic groups in July.

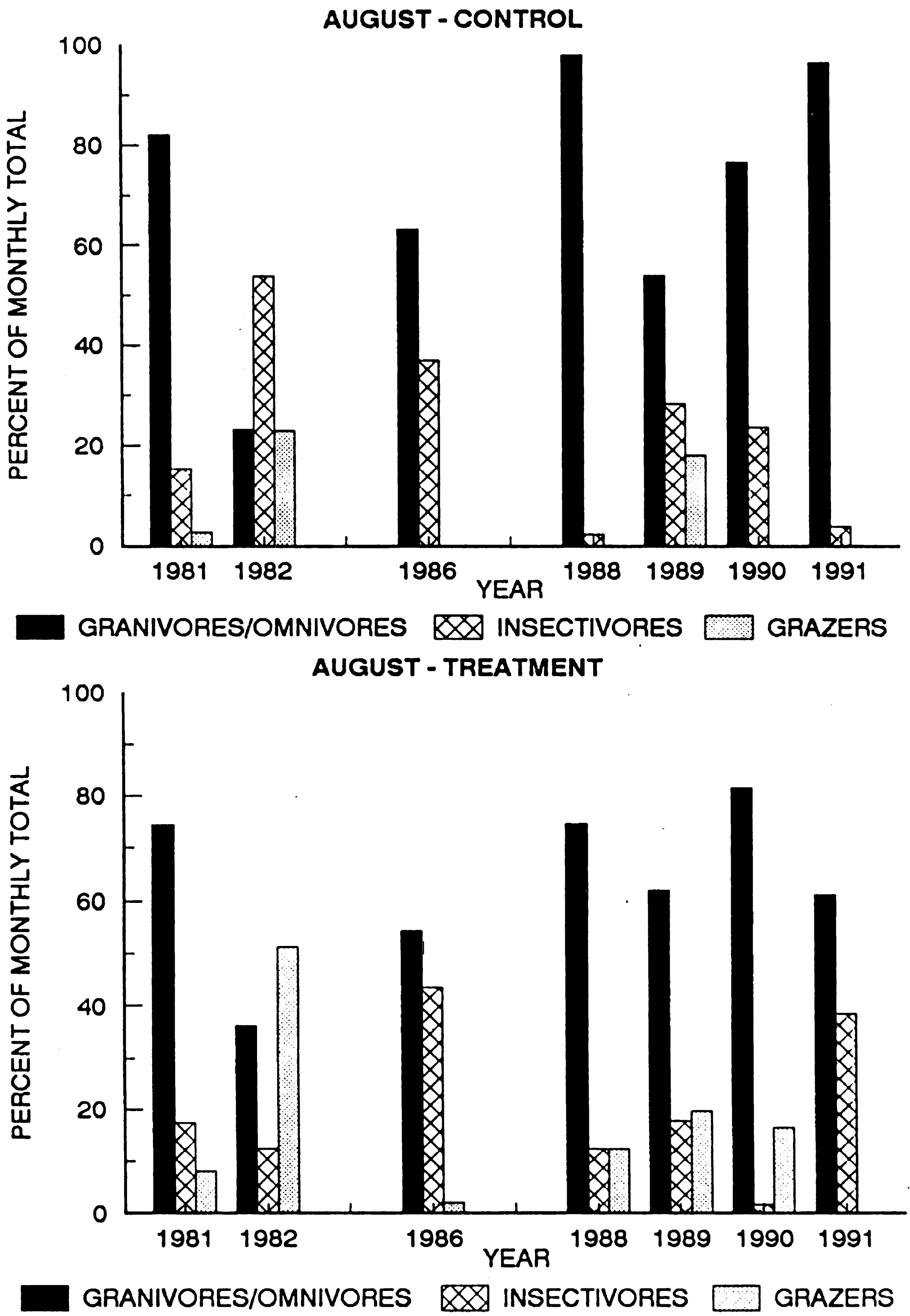

Figure 7. Percent of monthly total number of individuals trapped occurring in each of 3 trophic groups in August.

shift also occurred in 1988, when nearly equal proportions of granivores/omnivores and grazers were present in July, but grazers were absent while granivore/omnivore abundance increased in August. Insectivores were absent in July 1989, but comprised 28% of the monthly total in August. Similarly, the proportion of insectivores increased on the control plots from July to August in 1990 (Fig. 6 and Fig. 7).

Monthly variations in trophic group total abundance were less extreme on the treated plots. Insectivores were absent in July and present in August 1982, and also increased in proportion in 1986 (Fig. 6 and Fig. 7). In both 1988 and 1989 the proportion of grazers decreased considerably in August, while the granivore/omnivore group increased.

On both treated and control plots there was a general trend of fewer grazers and more insectivores from July to August (Fig. 6 and Fig. 7).

DISCUSSION

VEGETATION CHARACTERISTICS

Whole-tree harvesting produced several obvious, and some less conspicuous, changes on the treatment plots. Removal of all stems > 5cm dbh dramatically reduced the total stem density and % cover > 1m in height, creating an open, "old field" vegetation type. Less obvious were changes in species composition of the remaining vegetation. Plant species typical of early successional stages quickly colonized the site. Although the mean % cover < 1 m remained stable near 95%, species composition was very different between treatment and control plots. Ground cover on the control plots was comprised of shade tolerant species such as bunchberry, baneberry, twisted stalk, and anemone. Treated plots were dominated by asters, goldenrods, *Rubus* spp., strawberry, blueberries, grasses and sedges, and other species typical of the disturbed or early successional sites.

Within 2-3 years after treatment, regeneration of aspen clones resulted in stands of aspen sprouts on the plots. The density of aspen regeneration was highly variable, ranging from dense to sparse. Very dry, sandy sites were dominated by bracken fern and a sparse cover of aspen sprouts, while moderately drained soils produced more dense stands. In addition to aspen, several woody shrub species, including dogwoods, alder, chokecherry, steeplebush, withe rod, and winterberry holly, rapidly colonized the sites, forming very dense stands that appeared to out-compete aspen in some areas. Several wetland species, including cattails, sedges, rushes, and willows, colonized the wettest areas and remained dominant for the duration of the study.

Rapid growth of the aspen clones, and several other species such as alder and dogwoods, quickly provided conditions suitable for more shade tolerant species, which colonized the treated sites from the adjacent forest. This resulted in a mosaic of vegetation types on the treated plots, including small areas of cattail/sedge marsh, alder and willow swales, grass/forb communities lacking overstory cover, sparse aspen sprouts interspersed with bracken and sweet fern, and dense aspen regeneration with a forb understory similar to the adjacent forest.

Vegetation on the control plots also underwent successional changes throughout the study. As over-mature aspen thinned due to windthrow and heartrot, the percent canopy cover in the > 7m stratum decreased. Percent ground cover was significantly negatively correlated with the density of trees > 30cm dbh, but not with percent cover in the > 7m height stratum, probably due to the clumped distribution of gaps on the plots.

BREEDING BIRD POPULATIONS

Bird Species - Vegetation Associations

Territories were mapped for 16 species that were classified as very uncommon, which caused an increase in the diversity index in some years. These species may have been uncommon for a variety of reasons. For example, some species are not usually abundant, even in optimum habitat, due to large territory size. Some species may have utilized the plots only in years when optimum habitat was saturated or altered elsewhere. The 6 habitat generalist species used both treatments and controls in various years from 1986-1991, and would likely find suitable habitat in many vegetation types. The open/edge species are obviously favored by practices that provide early successional vegetation, and thus allow the opportunity to increase the Gamma diversity in heavily forested areas. Population and guild trend data in this and other studies (Webb et al. 1977, Yahner 1987a) indicate that the response is short-term, and thus frequent harvesting (8-10 years) of forested blocks would be required to maintain maximum avian diversity in large tracts of mature aspen forest. However, some birds in the "mature aspen species" category require large areas of mature trees to maintain viable populations. Species with very large territories (pileated woodpecker, barred owl, goshawk) were not included in the analysis for this study, and require special consideration in any regional forest management strategy.

Bird Species - Vegetation Correlations

The negative correlations of the density of stems in both the > 30cm dbh and the 20-30cm dbh size classes with the percent ground cover (< 1m) suggest that areas with low densities of larger trees might have a higher proportion of ground cover. This is likely due to the absence of cover in the upper strata, allowing greater sunlight penetration and thus more light in the lower stratum. Forested areas of this type might also have more trees in the lower strata (saplings and 10-20cm dbh), due to the abundance of light and lack of competition by larger trees. This might explain the negative correlation between density of stems 10-20 cm dbh and ovenbird abundance. Bent (1963a) reported that ovenbirds typically nest "where the underbrush and growth of shrubs and small trees is scanty, and the forest floor is open below and carpeted with old leaves." Thus, it appears that ovenbirds may be an exception to a positive relationship that may exist between ground nesters and ground cover on the controls.

Field sparrows typically inhabit shrub grasslands and old fields with scattered woody vegetation (Best 1979), and shrubby growth, grassy meadows, weedy fencerows, and pastures (Walkinshaw 1936). Percent shrub crown cover (< 5m tall) and density of small diameter (< 2.5cm) stems are considered limiting factors for reproductive habitat (Sousa 1983). Optimum values for these variables are between 350-700 stems/ha and 15-35% shrub cover (Sousa 1983), much lower than the values for any year on the treated plots during 1986 through 1991. Total stem density was significantly correlated with total percent cover on the treated plots. Thus it follows that this primarily grassland associated species was negatively correlated with the absolute density of aspen, the most abundant woody species on the treated plots.

Red-winged blackbirds nested in small, scattered areas of cattails (Typha sp.), sedges (Carex sp.), and bulrush (Scirpus sp.) on the treated plots. Occurrence of tall, dense, herbaceous vegetation of this type is considered a limiting factor for nesting (Short 1985). A possible explanation for the negative correlation between red-winged blackbird abundance and cover in the 1-7m stratum may be the tendency of alder, willow, swamp white oak, and aspen in this stratum to replace the robust, herbaceous vegetation (cattails, sedges, bulrushes) favored for nesting by these birds.

Song sparrows prefer low, brushy vegetation in wetlands, such as brushy shores of ponds, shrubby wet

meadows, cattail swamps, salt marshes, and other lowland areas. Nests are placed in grasses, sedges, cattails, bushes and shrubs, and, rarely, trees (Bent 1968). Thus, it is likely that the abundance of this species was highly negatively correlated with the density of alder and willow for the same reason cited for red-winged blackbirds: these woody wetland species eventually replaced the low, shrubby habitat preferred by song sparrows for nesting.

The highly significant negative correlation between yellow warbler abundance and the absolute density of alder is inexplicable, as it is contrary to many published accounts of the habitat preferences of this species. Morse (1966) stated that preferred foraging and nesting habitats are wet areas, partially covered by alders and willows 1.5-4m in height. Bent (1963b) reported that alders, willows, and other hydrophytic shrubs and trees are preferred for nesting. Van Velzen (1981) reported that 100% of shrub wetland types were used, and shrub dominated wetlands had the highest breeding densities of all cover types included in several breeding bird census reports. Schroeder (1982) assumed, in formulating a habitat suitability index model for the species, that optimal habitats contain 100% hydrophytic deciduous shrubs . Based upon these criteria, one would expect a highly *positive* correlation between yellow warbler abundance and the density of alders.

Avian Abundance, Species Richness, and Diversity

Thompson and Fritzell (1990) reported that the breeding season abundance of some interior forest bird species (ovenbird, great crested flycatcher) decreased in adjacent (untreated) forest 3 years after a 4.5 ha stand was commercially clearcut. They found similar decreases in forest adjacent to clearcuts ranging from 1 to 2 ha in size. Such decreasing trends were not evident in this study on the control plots 5 years after the treatment plots were harvested. In contrast, the density of ovenbird and great crested flycatcher territories in the forest near the treated plots were above pre-treatment levels 5 years after treatment, and generally remained at or above this level for both species. Also, contrary to the findings of Thompson and Fritzell (1990), this study found greater species richness and diversity in the clearcut plots than in the mature forest. Higher species diversity may be attributed to greater numbers of individuals as well as species on the treated plots. Higher species richness would not be expected on the clearcuts due to the lower vertical diversity associated with removal of the canopy (MacArthur and MacArthur 1961). However, several bird species typically considered interior forest species utilized portions of the clearcuts in their territories, which increased the total number of species on the treated plots. In addition, vegetative composition of the treated plots was highly variable, perhaps resulting in greater bird species diversity than in similar studies. Total bird densities were nearly 2 times higher on the treated plots than on the controls 5 to 7 years after treatment. This was similar to the findings of Thompson and Fritzell (1990), but contrary to those of Yahner (1986b), who found bird densities in 5 to 8-year-old clearcuts only slightly higher than in adjacent mature forest. Total bird densities on both the treated and control plots may have responded to changes in the local habitat, or nearby habitat, causing population fluctuations as the habitats changed. If the study plots were sites of immigration and/or emigration, they would not actually reflect the quality of the habitat provided (Wiens and Rotenberry 1981).

Thompson and Fritzell (1990) also reported that species which use early successional vegetation increased in abundance in adjacent forest. This trend was exhibited by common yellowthroats in this study. In the years of maximum abundance on the treated plots (1988 and 1989), a few individuals of this species established territories on the nearby forested plots, perhaps in sub-optimal natural openings in the stands. This may have also been in response to high competitive pressure for territories in the high abundance years (Table 7 and Table 8).

A similar, reverse trend was observed for several species normally associated with mature forest. Black-capped chickadee abundance was highest on the control plots in 1989, and a few territories were mapped for this species on the treated plots only in this year. Red-eyed vireo abundance was relatively high on the control plots in 1986 and 1988, and the species was also found on treated plots in these years. Ovenbirds, wood thrushes, eastern wood peewees, and veerys were at or near their highest levels of abundance for the study in the mature aspen in 1986, and several territories were mapped for these species on the treated plots in this year (Table 6 and Table 7).

In addition to possibly responding to habitat saturation on the control plots, the ovenbird, eastern wood peewee, and veery may have exhibited site tenacity for their original, yet perhaps less suitable habitat on the treated plots in 1982. These species were very abundant on the designated treatment plots in 1981, and a few individuals established a territories on the newly harvested plots in 1982 (Table 8). Van Horne (1983) discussed a phenomenon observed by Rotenberry and Weins (1978) in which site tenacity in breeding passerines produced local densities that reflected past, rather than current habitat quality.

It appears that the overall trend in total bird density on the treated plots was towards a return to pre-treatment conditions. However, species composition was different between treatment and controls, and probably would remain so for many more years. These results are contrary to those found by Webb et al. (1977), who reported that species composition, in addition to abundance, returned to pre-treatment levels after 10 years on conventionally harvested clearcuts.

Avian Guild - Habitat Relationships

Several trends were identified in species abundance within avian guilds relative to vegetation structure and composition.

Species in the ground forager and ground nester guilds appeared to respond to changes in cover in the 1-7m and < 1m stratum, respectively (Fig. 8). A positive relationship between ground nesting birds and ground cover is quite logical, as sufficient cover is necessary to provide suitable nesting sites for a variety of species. However, reasons for a positive relationship between the number of ground foraging species and cover in the 1-7m stratum are less obvious. A partial explanation might be the fact that many ground foraging species are shrub nesters.

While a positive relationship between cover in the 1-7m stratum and some ground associated species apparently existed in the mature aspens, the opposite appears true in the early successional habitat. As the absolute density of alder and willow, total stem density, total cover, and thus cover in the 1-7m stratum increased from 1986 through 1991, the number of species in the ground associated guilds

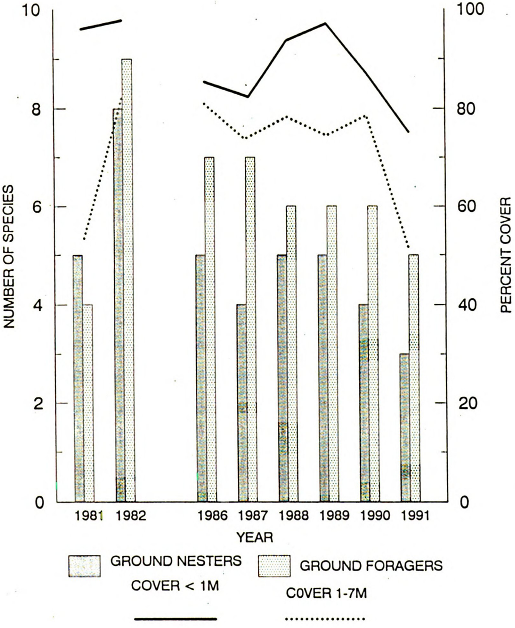

Figure 8. Relationship between percent cover < 1m, percent cover 1-7m, and the number of avian species in each of 2 guilds on the control plots.

decreased. When cover in the 1-7m stratum decreased in 1991, the number of ground associated species increased (Fig. 9). The mean percent cover in the < 1m stratum remained relatively constant, suggesting a response to mid-story cover. A shift in ground cover species composition may provide an explanation for these trends. The absolute frequencies of Canada mayflower, lichens, and mosses increased from 6-8% to 75-90% from 1986 to 1989, concurrent with an increase in cover in the 1-7m stratum from 23% to 50% cover. It is probable that ground associated species in early successional vegetation prefer more herbaceous ground cover.

Conversely, the shrub/sapling nesting guild appeared least sensitive. Despite complete removal of the > 7m cover stratum and an 86% reduction in cover in the 1-7m stratum between 1981 and 1982, 4 species were found in this guild in both years (Table 10). The fact that a significantly higher density of sprouts and shrubs < 5cm dbh was present on the treated plots in 1982 probably minimized the impacts upon this guild.

Implications of Snag Removal

Cavity-nesting species were lacking on the treated plots throughout the study. Although 1 tree swallow and 2 black-capped chickadee territories were mapped on treated plots in some years, these birds were known to nest in snags

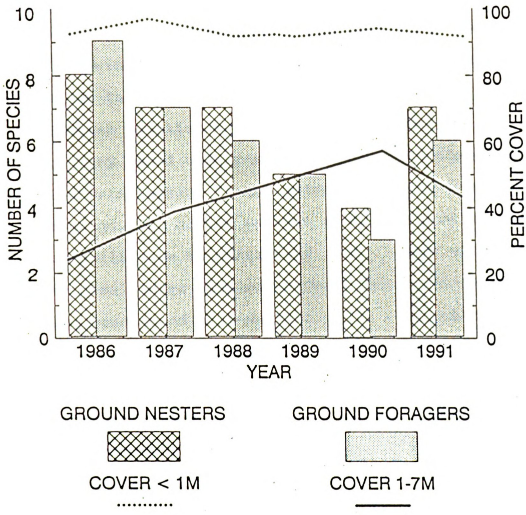

Figure 9. Relationship between percent cover < 1m, percent cover 1-7m, and the number of avian species in each of 2 guilds on the treatment plots.

off the plots. In contrast, 5 cavity-nesting species established a total of 31.4 territories/ha on the control plots during the 1986 through 1991 period. This is attributed to the fact that no snags remained on the treated plots following whole-tree harvesting, while snags were abundant on the control plots after 1986.

Similar results were reported by Dickson et al. (1983). They found cavity-nesting species virtually absent from clearcuts lacking snags, present on plots where snags were retained, and higher species richness, bird abundance, and equitability on snag-retained plots. They noted that 44 of 75 original snags remained 4 years following treatment of the plots, and found that smaller snags (< 40cm dbh) tended to fall before larger snags. The authors speculated that total bird abundance was higher on the snag-retained plots due to the importance of snags as foraging sites and perches for other (non-cavity-nesting) species such as summer tanagers, black-and-white warblers, blue jays, and brown-headed cowbirds.

Thompson and Fritzell (1990) also reported the establishment of territories by 7 cavity-nesting species in clearcuts in which snags were retained. Yahner (1986b) found snag densities correlated with bird species richness, and the abundance of downy woodpeckers and black-capped chickadees. The importance of snags to the regional distribution of woodpeckers and other cavity-dependent wildlife has been discussed by Galli et al. (1976) and Yahner (1983a). The role of large numbers of standing live trees and snags in clearcuts for minimizing habitat loss for tree dependent birds was stressed by McClelland and Frissell (1975) and Tobalske et al. (1991). Many literature reviews have indicated that the availability of snags is the main limiting factor for primary and secondary cavity-nesting birds (Bruns 1959, Gysel 1961, Haapanen 1965, Beebe 1974, Thomas et al. 1975).

Snags retained in clearcuts are particularly important to species such as the eastern bluebird and common flicker. Bluebirds refuse to nest in dense woods, preferring natural cavities in snags located in savanna-like vegetation types or old fields (Rustad 1972, Hardin and Evans 1977, Crawford et al. 1981a). Clearcuts are especially valuable nest sites, as they provide the necessary habitat away from human population centers where competition from starlings and house sparrows limits the availability of nest sites. Eastern bluebirds and common flickers were among the most numerous species nesting in dead snags in a study of conventional clearcuts by Connor and Adkisson (1975). Flickers prefer to excavate cavities in trees greater than 50cm dbh that have been dead for more than 5 years (Bull et al. 1986). They prefer to forage on the ground, often in open grasslands, and are noted for nesting in clearcuts (Hardin and Evans 1977, Bull et al. 1986).

Eastern bluebirds were observed on harvested plots during 3 years of this study, while starlings were observed in only 1 year, and no house sparrows were observed (Table A-3). Common flickers were observed on treated plots in every census year, but no evidence of nesting on the plots was found. Anderson and Shugart (1974) found that downy woodpeckers were highly correlated with the abundance of saplings in Tennessee deciduous forests. Thus, clearcuts with snags retained might be particularly favorable foraging sites for this species. It is likely that the retention of snags would have significantly increased the value of the harvested plots as nesting sites for eastern bluebirds, common flickers, and downy woodpeckers.

In addition to their importance as nesting sites, rough barked snags retained in clearcuts provide arthropods for trunk-bark foragers, such as downy woodpeckers and black-capped chickadees. Back (1982) also discussed the importance of live overstory trees and snags retained in clearcuts as song perch sites.

RUFFED GROUSE DRUMMING ACTIVITY

Increasing Trend

The number of grouse drumming on the 129.5 ha site exhibited an increasing trend during the study (Fig. 5). This may be attributed to the combined effects of increased brood habitat provided by the treated plots, and an increase in favorable drumming habitat as the mature forest became more dacadent.

Grouse broods prefer forest edges, such as found along small or narrow semi-shaded clearings, secondary roads, trails, and forest openings with an abundance of herbaceous plants, woody sprouts, shrubs and seedlings, and berry bushes (Bump et al. 1947, Stewart 1956). Such areas were scarce in this heavily forested tract prior to treatment, provided only by small, scattered natural openings in gaps created by windthrown aspens. The treated plots and associated access roads provided an additional 17.5 ha of this habitat within 5 years after treatment.

Kubisiak (1978) reported that broods seldom use sprouting aspen that is less than 5 years old, but the stands provide prime habitat between 5 and 15 years. Similarly, Polderboer (1942) found that grouse avoided weedy clearings < 3 years old, but used 6-7 year old clearings extensively. These observations are probably related to the canopy coverage, as Godfrey (1975) reported that the major canopy component was between 3 and 8 meters in height. Gullion (1977a) defined optimum brood cover as having 19,000-25,000 stems/ha, while Kubisiak (1978) observed brood use of areas with total stem densities up to 33,000 stems/ha. Total stem densities on the treated plots first approached these ranges in 1987 (Table 3). Stem density on the treated plots was positively correlated with the number of drumming grouse (Table 12), but grouse did not utilize the plots for drumming. Thus, it is logical to propose that the plots may have contributed to the increase in drummers by increasing the survival of broods. The mean number of grouse drumming on the site from 1981 through 1986 was 6.8 (S.E. = 0.61), while a mean of 10.8 (S.E. = 0.84) drumming grouse was found for the period 1987 through 1991 (Fig. 5). The increase in drummers in 1987 may have been the result of higher brood survival beginning in 1986, 5 years after treatment and coincidental with the expected increase in brood habitat. Sharp (1963) stressed the importance of good brood habitat for increasing the adult population, and stated that brood rearing niches in mature forest are scarce, poor in quality, and lead to low adult populations. Berner and Gysel (1969) concluded that good brood habitat is the single most important factor in increasing grouse populations, as adults can survive without it, but broods cannot. Grouse broods were observed on 2 of the treated plots in 1988, and on all 3 from 1989 through 1991. In 1990, the year prior to maximum drummer abundance, 2 broods of 10-12 chicks and a brood of 7 or 8 chicks were observed feeding on the plots. It is likely that the increased area and quality of brood habitat on the site contributed to the increase in the number of grouse drumming on the area.

The amount of favorable drumming habitat in the mature forest also increased during the study. It was found that the number of drumming grouse on the area was highly negatively correlated with percent cover in the > 7 M height stratum (Table 12). From 1986-1991, cover in this stratum decreased, especially during the final 3 years (Table 2). This decrease was likely due to the gap-forming successional stage of the aspens. Thus, grouse found an increasing amount of favorable drumming cover during the study, resulting in an increase in drummers due to higher survival rates and immigration.

Avoidance of Treated Plots

Despite the increasing trend and near doubling of drumming grouse numbers on the study area from 1981 through 1991, drumming grouse were never observed on the treated plots, nor was any evidence found indicating that the plots were used for drumming. In contrast to other studies, a general trend of avoidance of the treated plots was exhibited by drumming grouse. Schulz (1984) found a 33% increase in drumming grouse within 40m of a clearcut in the first year following harvest, and a 67% increase in the next year. An opposite trend was exhibited by grouse in this study. Four of the 7 drumming grouse (57%) found on the site in 1981 (pre-harvest) were within 40m of a designated treatment plot. However, in the first year following treatment (1982), only 29% of the drumming logs were within 40m of a clearcut. The percentage increased slightly to 40%

in 1983. Of the 38 drumming logs found during the study, only 66% were within 200m of a treated plot.

Gullion and Marshall (1968) found that grouse which periodically moved to different drumming logs doubled their life expectancy, from 17 to 34 months. He suggested that habitat around transient logs is basically poorer than that around perennial ones. Thompson and Fritzell (1989) supported this conclusion, and found significant differences in vegetation characteristics around perennial, transient, and non-drumming sites. They concluded that the vegetation characteristics of transient sites were more similar to non-drumming sites than to perennial sites. The fact that 52% of the drumming logs in this study were transient sites suggested that the mature forest on the study area did not provide an abundance of optimum drumming sites. The frequent establishment of new drumming sites throughout the area implies mobility of the grouse in searching for suitable drumming sites, and frequent location and use of new areas (Fig. 4). Logically, if the treated plots provided areas suitable for drumming, they should have been discovered and utilized. However, the grouse continued to establish new drumming sites in the mature forest, avoiding the (theoretically) suitable treated plots.

Mean stem densities on the treated plots were in the range suitable for drumming grouse from 1986 through 1991. Gullion (1970, 1977b) reported that aspen regeneration was first used by drumming grouse 8-12 years after treatment, when stem density was between 14,000-20,000 stems/ha. Carlson (1984) found a mean density of 1 drumming grouse per 6.13 ha in conventionally harvested clearcuts with a mean stem density of 22,074 $\pm$ 1571 stems/ha in northern Michigan. Total stem densities on the treated plots in this study were within this range in 1990 and 1991, when the plots should have provided sufficient habitat area (17 ha) for approximately 3 drumming grouse (1 per plot) based upon this criterion. Hunyadi (1984) reported total stem densities between 13,412-15,296 stems/ha in the immediate vicinity of drumming logs in Missouri. Stem densities within 0.01 ha circular plots centered on the placed drumming structures were within this range in 1991 (Table 10). Hammill and Moran (1986) estimated that any stem density > 14,000 stems/ha around drumming logs is optimum in Michigan. Hammill (pers. comm.) reported that the availability of drumming logs is not considered limiting for grouse in the Upper Peninsula of Michigan. He found grouse drumming on broken saplings and poles, rocks, and even the ground, when all other habitat requirements were met on the site. As several drumming grouse were located within 40m of the treated plots in this study, the basic life requisites of male grouse were obviously met in the immediate vicinity of the treatments. Thus, grouse would be expected to use the treated plots for drumming, even if the placed structures were not accepted.

The combined effects of several factors might explain the unsuitability of the treated plots for drumming. Hunyadi (1984) reported 63-65.7% canopy coverage above drumming logs in Missouri. Thompson and Fritzell (1989) reported even higher canopy coverage, 73% above perennial and 83% over transient drumming logs. These values exceed the mean percent canopy cover on the treated plots in every year except 1990 (Table 2). Similarly, Kelly and Major (1979 in Backs 1984) reported that grouse drummed in clearcuts with a mean stem density of 35,000 stems/ha (< 13 cm dbh), while clearcuts with mean stem density of 20,775 stems/ha were not used. These densities exceed total stem densities found on the treated plots throughout the study (Table 3). Hunyadi (1984) reported a range of 47.4-72.5% ground cover around active drumming logs. This range is considerably lower than percent ground cover found on the treated plots in every year of measurement (Table 2). In addition, percent ground cover was negatively correlated with the number of grouse drumming on the control plots (Table 11). Thus, the treated plots may have been unsuitable due to excessive shrubby (horizontal) cover < 1m in height (dogwood, *Rubus* spp., etc.), which limits the horizontal vision of drumming grouse, and insufficient canopy (vertical) cover from raptors. Optimal drumming sites provide cover from aerial predation, and have sparse amounts of low vegetation which provides cover for terrestrial predators (Bump 1947, Gullion 1970, Porath and Vohs 1972). Gullion and Alm (1983) reported that nesting goshawks effectively eliminated the population of drumming grouse on a 1 ha study area, and substantially depressed drumming grouse numbers in another area during separate study periods. The populations on both sites significantly increased in years when goshawks were absent. He concluded that the birds were generally killed in the vicinity of the drumming log, but very rarely while actually on the log (Gullion and Marshall 1968). Hammill (pers. comm.) reported similar results with nesting goshawks in Michigan. Goshawks were observed on the plots in this study in 1981, 1982, and 1990, and nested at least in 1981 and 1982. They may have been present, yet undetected, in other years as well, combining with the above vegetative deficiencies to make the treated plots unsuitable for drumming grouse.

SMALL MAMMAL POPULATIONS

Population Trends

No consistent trends could be identified in annual abundance on the treated or control plots. Irregular fluctuations in small mammal populations were also reported by Krull 1970.

The only trend evident in small mammal abundance was in the similarities between abundance on the treated and control plots in the same years. In general, abundance was very similar prior to and immediately following treatment in 1981. July populations on treated plots and controls were very different and fluctuated radically between 1982 and 1988, but relative abundance appeared to become synchronized between treatments and controls during 1989-1991 (Table 13).

Yearly population fluctuations may have been in response to regulatory variables acting upon the populations on both treatment and control plots. It is possible that the treatment introduced a second set of variables (treatment effects), perhaps linked to vegetative structure, that upset the synchronization of abundance on the treatment and control plots. The fact that "total" abundance was very similar on all plots in 1981, then again in 1989 through 1991, despite extreme annual variations, suggests that the effects of the treatment on July populations may have been minimized by 1989, 8 years after harvesting.

Small mammal species richness also fluctuated annually and monthly on treatment and control plots. However, a trend identical to the one previously suggested for abundance was also evident for species richness. Although the mean number of species per plot fluctuated annually, the value was more similar for treatment and control plots in each month than for the same plot in different months (Table 15). In general, species richness appeared higher on the treated plots in both July and August. A greater diversity of microhabitats might have been provided on the treated plots. Sedge-cattail wetlands, blueberry patches, forbs, grassy openings, dense woody shrubs, alder and willow thickets, and aspen regeneration were abundant on all of the treated plots. Conversely, ground cover on the control plots was primarily dominated by a dense understory of shade-tolerant forbs, bracken fern, and woody shrubs. Open or grassy areas became available on the control plots as the gap-forming phase progressed, possibly explaining the increasing trends in species richness on the treated plots in July and August 1988-1991 (Table 15). Dueser and Brown (1980) in Yahner (1983b) concluded that the number of small mammal species coexisting in a given habitat is principally determined by the size of the stand and the diversity of microhabitats within it.

Thus, alteration of the vegetative structure (treatment) appeared to have less effect upon small mammal populations than unknown mechanisms regulating July and August species composition and abundance. Effects of the treatment were apparently short-term. Although "total" abundance and species richness on all plots fluctuated annually, similar values were observed for all plots in 1981 and 1989 through 1991. This conclusion was supported by Brooks and Healy (1988), who found comparable results in clearcut, sapling, and mature eastern hardwoods. As in this study, they concluded that small mammal populations were

similar in sapling and mature hardwoods, and that the effects of clearcutting were minimal and ephemeral. Buckner and Shure (1985) found that large forest openings in early successional stages can provide a combination of variables that represent forest-like structural features, and documented a response of small mammals to these variables. M'Closkey and Lajoie (1975) also found that floristic composition was unimportant to white-footed mice, as population covaried with foliage profile structure. Yahner (1986a) also stressed the importance of microhabitats, microclimates, and diversity of vegetative growth forms in determining small mammal distributions in aspen stands. Dueser and Shugart (1978) found evidence of microclimate segregation and related vegetative structure to the distribution of 3 small mammal species. Thus, it appears that interactions between several habitat components, in various combinations, result in rapid fluctuations in species composition and abundance.

Trophic Group Trends

Contrary to the findings of Kirkland (1977), trends in trophic group responses to clearcutting were not evident in this study. Analysis by trophic categories suggested that small mammal populations differed more between trapping period (July vs. August) than between treatments. Evidence of temporal shifts in species composition and abundance suggests that different regulatory mechanisms may influence the populations during July and August. Quimby (1951) concluded that the vegetational type alone was not the controlling factor in determining the presence of jumping mice, and that their preference for vegetational types may differ by month. Thus, the "August" mechanisms may have been altered by the treatment, or responded differently than the July regulatory factors, and had not yet returned to pre-treatment levels by 1991.

It is also possible that the mechanisms responsible for the shifts in relative abundance, species diversity, and trophic groups were independent of the treatment. For example, Getz (1961a) found that moisture was the most limiting factor in the local distribution of shrews, and concluded that the type of cover, temperature, and interspecific competition were not important factors. The relative abundance of short-tail shrews in this study was negatively correlated with mean temperature in August. In all years for which trophic group data were available, August was both cooler and wetter than July (Table 1). Thus, the increase in insectivore abundance from July to August on both treatment and control plots may have been the result of an increase in the amount of habitat provided by the sites. Above average rainfall in August might have produced large areas of suitably moist habitat (microclimates) that were too dry in July. As the soils on these sites are poorly drained, they hold moisture much longer than nearby uplands. Thus, the study area might provide high quality habitat for shrews under these conditions. Similarly, in dry years, the poorly drained sites on the area would retain moisture later into the summer. Thus, as microhabitats became desiccated in other areas in August, shrews may have immigrated onto the study plots, increasing the relative abundance. Getz (1961a) stressed the affinity of shrews for moist lowland sites, and described the rapid colonization of a marsh as soon as the standing water disappeared in one summer.

It is possible that other mechanisms, also independent of the treatment effects, could influence the distribution and abundance of small mammals between July and August. Insects and other invertebrates might become more abundant or vulnerable to insectivores in August, allowing for rapid population increases in small mammal populations. Similarly, more grass seeds and fruits of forbs are available in late summer, favoring the granivore/omnivore group. Response to temperature might also account for some of the apparent shifts in abundance of individual species and trophic groups. Getz (1961b) found a relationship between the activity of meadow voles and temperature, and Orr(1959) reported similar results for white-footed mice. In this case, favorable temperature could simulate a population increase between months when in fact none had occurred. An increase in activity would result in the capture of a greater proportion of the individuals on the plots, erroneously interpreted as a population increase.

SUMMARY

The impacts of whole-tree harvesting of aspen on breeding birds were drastic and relatively short term. Species composition was homogeneous among plots prior to treatment in 1981, and became more heterogeneous following harvest. Bird species richness, abundance, and diversity on the treated plots decreased dramatically immediately after harvesting, exceeded pre-treatment levels during years 5-7, and approached pre-treatment levels within 10 years. Based upon the breeding habitat utilized by birds, several species associations were identified: some species were found exclusively in the early successional habitat, some used only the mature aspen, others exhibited shifts in utilization between treatments as succession progressed, and a fourth group established territories in both vegetation types throughout the 10 year period. Significant correlations were identified between vegetative variables and several bird species on the treated plots. Negative relationships between the number of species in the ground associated guilds and cover in the 1-7 m height stratum were also identified.

Five cavity nesting species established territories when aspens on the control plots exceeded 54 years of age.

The number of species in the foliage forager, flycatcher, and tree nesting guilds exhibited a positive relationship with the amount of cover in the < 1 m and > 7m height strata. Contrary to my hypothesis, species diversity increased in the 55 to 60 year-old aspen, and converged with the treated plot values in 1990 and 1991. In general, foliage height diversity became more homogeneous between treatments as the mature aspen entered the gap phase, and aspens on the treated plots matured.

The number of ruffed grouse drumming on the study site exhibited an increasing trend beginning 5 years after treatment, perhaps in response to the additional brood cover provided by the clearcuts of this age. Grouse were never observed drumming on the treated plots, and seemed to avoid them for drumming. Insufficient vertical cover due to low density, clustered regeneration of aspens is a potential explanation.

Small mammal species richness, abundance, and diversity fluctuated dramatically throughout the study, masking possible treatment effects. Analysis by trophic groups indicated that populations were more similar on different plots during the same month than on the same plot in different months. Thus, temporal effects were greater than those of treatments. Small mammals appeared to respond to temperature and precipitation.

RECOMMENDATIONS

In very large, contiguous, forested tracts of mature aspen (several hundred to thousands of hectares), as are found in some areas of the Lake States, whole-tree harvesting is a valuable technique for enhancing biodiversity and habitat quality. A "checkerboard" pattern of clearcuts, spaced to maximize interspersion and juxtaposition of vegetation types and age classes, would provide the greatest potential for increasing biodiversity in such areas. In addition, such management would retain the aspen forest cover type, (important to many species of Lake States wildlife), while meeting the increasing demand for timber and pulpwood production in the area. However, timber and wildlife management plans of this type should be carefully evaluated in terms of long term effects and forest fragementation. Management of large forest tracts should be integrated into a regional management strategy that considers habitat for "interior" species, and those requiring large forested tracts. Loss of such habitat and its associated species ultimately results in decreased biodiversity.

In this study, whole-tree harvesting in a large block

of mature aspen appeared to enhance the ruffed grouse population by providing brood habitat. Many other species utilize such areas, including the wild turkey (Meleagris gallopavo), American woodcock, white-tailed deer (Odocoilus virginianus), black bear (Ursus americanus), elk (Cervus elaphus) cottontail rabbit, and a diversity on nongame species. The clearcuts provided habitat for many avian species requiring early successional vegetation, increasing species richness and thus Gamma diversity in the study area.

Gullion (1984) proposed a variety of treatment options for the long term maintenance of aspen for wildlife. All options rely upon clearcuts to regenerate aspen clones, and are applicable to whole-tree harvesting. The following recommendations, adapted from Gullion (1984), are suggested to optimize wildlife habitat benefits associated with whole-tree harvesting of aspen:

1) Consider timing of treatments (winter vs summer) to maximize benefits from desired density of aspen regeneration (brood cover vs drumming cover, etc.).

2) Consider interspersion, juxtaposition, and topographic features (waterways, roads, etc.) and adjacent properties to optimize edge and desired habitat benefits.

3) Consider stand condition (maturity, disease, etc.) and site index when planning location and timing of treatments.

4) Consider size of the treatment area relative to the stand (large, contiguous block vs small woodlot) when setting wildlife habitat management objectives.

5) Vary size and shape of treatments according to topography, marketability, etc., but maintain within 0.5 to 5 hectares for optimum wildlife use.

6) Seeding and maintaining woods roads and log landings as permanent, herbaceous openings benefits many wildlife species.

In addition to these general recommendations, the following guidelines specifically address concerns relative to avifauna, ruffed grouse, and small mammal populations, based upon this research and supported by the findings of several other authors.

BREEDING BIRDS

Intensive timber management practices can remove existing snags, reduce or eliminate the recruitment of new snags, and diminish the probability of trees ever becoming large enough to provide the large snags required by some species (Thomas et al. 1979). This is particularly true with aspen management, which stresses short rotations and whole-tree harvesting to utilize all woody material prior to the start of decay. Thus, intensive management and extensive whole-tree harvesting of aspen could potentially eliminate large tracts of habitat for the 36 species of cavity-nesting birds in the Lake States. In this study, cavity-nesting species did not establish territories on control plots until the stand exceeded 54 years of age. On excellent sites, aspen may not reach maturity until 60 years old (Jakes 1982). Thus, aspen on high quality sites should be allowed to reach maturity, and sufficient snags left to provide habitat for cavity-nesting species. Hart (1991) stressed the importance of "old growth" aspen in maintaining biodiversity in the central Rocky Mountains. This study suggests that over-mature aspen may have similar ecological importance in large areas dominated by aspen forests in the Lake States. Consequently, the author reiterates the following recommendations provided by Evans and Connor (1979) and Dickson et al. (1983):

1. Manage for the maximum feasible rotation age (highly variable for aspen, depending upon the site quality).
2. Leave a 0.1 ha clump uncut in every 2 ha clearcut.
3. Leave permanently uncut buffer strips along streams.
4. Retain at least 5 large snags (> 40cm dbh) per ha in clearcuts, and a minimum of twice as many smaller snags due to their more rapid rate of attrition.
5. Consider letting stands age to later successional stages as an option in areas with poor access or low site quality.

6. Consider the impacts of extensive cutting on interior forest species and those requiring large territories when planning extensive cutting for ruffed grouse management, etc.

These guidelines are inadequate for large woodpeckers that require extensive forested tracts. Yahner (1988) stated that continued clearcutting of habitat, such as for ruffed grouse management, may lead to insufficient areas of uncut habitat for these species. The minimum sizes recommended by Thomas et al. (1979) for managing hairy and pileated woodpeckers are 10.1 and 121 hectares, respectively.

RUFFED GROUSE

The density and distribution of aspen regeneration on the treated plots might not have provided suitable habitat for drumming grouse. Aspen regeneration was generally clustered on dry, sandy soils and moderately well drained sites, while sedges, cattails, willows, and alders dominated the wetter soils and large patches of bracken fern and blueberry covered the extremely dry upland areas. Schulz (1984) found more than twice as many aspen stems/ha in plots cleared in winter verses those cleared in summer to regenerate over-mature aspen. Higher stem densities and a more even distribution are obtained from winter harvests. The fact that the treated plots were harvested in summer many have reduced their utility for drumming grouse, but increased the suitability for grouse broods and passerines by providing a greater diversity of herbaceous cover, woody shrubs, and even wetland vegetation types. If production of ruffed grouse drumming habitat is a primary objective, winter harvests are recommended.

SMALL MAMMALS

It appears that whole-tree harvesting of aspen had minor and ephemeral effects upon the small mammal populations in this study. Small mammals were neither favored nor adversely affected by clearcutting, and presumably responded to other, unidentified population regulating mechanisms. The inconsistencies in relative abundance and species richness between months in the same year, in addition to annual population fluctuations, implies that long term small mammal trapping studies should be conducted in the same period (month, etc.) each year. Researchers should also be aware that variations in annual weather patterns might also influence species richness, abundance, and catch rate.

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APPENDIX

Table A-1. Species of vegetation found on study plots in Midland County, Michigan, from 1981 through 1991.

Herbaceous Vegetation	
Agrimony	(Agrimonia gryposepala)
•Anemone	(Amemone quinquefolia)
Anise root	(Osmorhiza longistyles)
Aster	(Aster spp.)
••Bartonia	(Bartonia virginica)
Bedstraw	(Galium borealis)
Bindweed	(Polygonum spp.)
Blake snakeroot	(Sanicula spp.)
Bluebead lily	(Clintonia borealis)
Boneset	(Eupatorium perfoliatum)
Bracken fern	(Pteridium aquilinum)
Bulrush	(Scirpus spp.)
Bunchberry	(Cornus canadensis)
Buttercup	(Ranunculus spp.)
Canada mayflower	(Maianthemum canadense)
••Cattail	(Typha spp.)
Club moss	(Lycopodium spp.)
Cinquefoil	(Potentilla spp.)
Clematis	(Clematis virginiana)
Clover	(Trifolium spp.)
••Common mullein	(Verbascum thapsus)
•Cowwheat	(Melampyrum lineare)
Dandelion	(Taraxacum spp.)
Dewberry	(Rubus hispisus)
Dock	(Rumex spp.)
Dodder	(Cuscuta spp.)
Dwarf enchanter's nightshade	(Circaea alpina)
••Evening primrose	(Oenothera parviflora)
False hellebore	(Veratrum spp.)
•False Solomon's seal	(Smilacina stellata)
Fern	(Polypodiaceae)
•Foamflower	(Tiarella cordifolia)
Fringed loosetrife	(Lysimachia ciliata)
Gall-of-the-earth	(Prenantges trifoliata)
••Golden heather	(Hudsonia tomentosa)
Goldenrod	(Solidago spp.)
Grass	(Graminaceae)
Heal-all	(Prunella vulgaris)
Herb-Robert	(Geranium Robertianum)
Hogpeanut	(Amphicarpa bracteata)
Honeysuckle	(Lonicera spp.)
Horsetail	(Equisetum spp.)
Indian hemp	(Apocynum cannabinum)
••Iris	(Iris spp.)
Ironweed	(Vernonia spp.)
•Jack-in Pulpit	(Arisaema triphyllum)
••Joepye weed	(Eupatorium maculatum)

Table A-1. (cont.'d)

Lettuce	(Lactuca spp.)
Lion's paw	(Prenanthes serpentaria)
Lopseed	(Phryma Leptostachya)
Mallow	(Malva moschata)
••Michigan lily	(Lilium superbum)
••Milkweed	(Asclepias spp.)
Mint	(Menitha spp.)
Moss	(Bryophyta)
Northern bugleweed	(Lycopus armericanus)
••Orange hawkweed	(Hieracium aurantiacum)
•Orchid	(Orchis spp.)
Pointed-leaved tick trefoil	(Desmodium glutinosum)
Prickley currant	(Ribes lacustre)
Prickley greenbriar	(Smilax hispida)
Purple meadow rue	(Thalictrum dasycarpum)
•Red baneberry	(Actaea rubra)
••Rose	(Rosa spp.)
Sedge	(Carex spp.)
Sharp-winged monkeyflower	(Mimulus alatus)
••Sheep laurel	(Kalmia spp.)
Shinleaf	(Pyrola spp.)
Soft rush	(Juncus effusus)
•Solomon's seal	(Polygonatum biflorum)
Spreading dogbane	(Apocynum androsaemifoilium)
Starflower	(Trientalis spp.)
Stinging nettle	(Urtica dioica)
Strawberry	(Fragaria spp.)
Sweet coltsfoot	(Petasites frigidus)
Tall rattlesnake root	(Prenanthes trifoliata)
•Thimbleweed	(Anemone virginiana)
••Thistle	(Cirsium vulgare)
•Trillium	(Trillium spp.)
•Twisted stalk	(Streptopus spp.)
Violet	(Viola spp.)
Water hemlock	(Cicuta maculata)
•White baneberry	(Actaea alba)
••Whorled loosestrife	(Lysimachia quadrifolia)
Wild Lily of the Valley	(Maianthemum canadense)
Wild sarsaparilla	(Aralia nudicaulis)
Yarrow	(Achillea Millefolium)

•species found only on control plots
•• species found only on treatment plots

Table A-1. (cont.'d)

Woody Vegetation	
Alder	(*Alnus* spp.)
American beech	(*Fagus grandifolia*)
American elm	(*Ulmus americana*)
Apple	(*Malus* spp.)
Ash	(*Fraxinus* spp.)
Balsam popular	(*Populus balsamifera*)
Basswood	(*Tilia americana*)
Bigtooth aspen	(*Populus grandidentata*)
Black cherry	(*Prunus serotina*)
Blueberry	(*Vaccinium* spp.)
Brambles	(*Rubus* spp.)
Bunchberry	(*Cornus canidensis*)
Burr oak	(*Quercus macrocarpa*)
Chokecherry	(*Prunus virginiana*)
Dogwood	(*Cornus* spp.)
Grape	(*Vitis* spp.)
Hawthorne	(*Pyrus* spp.)
Honeysuckle	(*Lonicera* spp.)
Ironwood	(*Ostrya virginana*)
Maple leaf viburnum	(*Viburnum acerifolium*)
Nannyberry	(*Viburnum lentago*)
Poison ivy	(*Toxicodendron radicans*)
Quaking aspen	(*Populus tremuloides*)
Red maple	(*Acer rubrum*)
Red oak	(*Quercus rubra*)
Ribes	(*Ribes* spp.)
Serviceberry	(*Amelanchier* spp.)
Slippery elm	(*Ulmus rubra*)
Steeplebush	(*Spirea latifolium*)
Swamp white oak	(*Quercus bicolor*)
Sweet fern	(*Myrica asplenifolia*)
Virginia creeper	(*Parthenocissus quinquefolia*)
White birch	(*Betula papyrifera*)
Willow	(*Salix* spp.)
Witch hazel	(*Hamamelis virginiana*)
Wintergreen	(*Gaultheria procumbens*)
Winterberry holly	(*Ilex verticilata*)
Withe rod	(*Viburnum cassinoides*)

Table A-2. Chronological occurrence and/or territory establishment of selected bird species observed on study plots from 1981 through 1991.

Species	Years of Occurrence
CONTROL PLOTS	
Species occurring primarily in 50-51 year-old aspens:	
Blue-winged warbler	1982
Chestnut-sided warbler	1981,81,90
Eastern phoebe	1981,82
Yellow warbler	1982
Species occurring primarily in 55-58 year-old aspens:	
Mourning dove	1986,87
Tree swallow	1987-89
Species occurring primarily in 57-60 year-old aspens:	
Alder flycatcher	1988,89
American woodcock	1988-91
Black-throated green warbler	1988-90
Northern cardinal	1988-90
Ruffed grouse	1989-91
Yellow-throated vireo	1989-90
TREATMENT PLOTS	
Species occurring in 1 year-old clearcuts	
Killdeer	1982
Species occurring primarily in > 5 year-old clearcuts	
Nashville warbler	1988,90,91
Ruffed grouse	1988-91
Turkey vulture	1987-89,91
Warbling vireo	1986-88,91
White-throated sparrow	1987,89-91
Yellow-billed cuckoo	1987-91
Yellow warbler	1986-91

Table A-2 (cont.'d)

Species	Years of Occurrence
Species occurring primarily in 5-8 year-old clearcuts:	
Alder flycatcher	1988,90,91
Broad-winged hawk	1988-91
Magnolia warbler	1987-89,91
Northern cardinal	1986-88,90
Red-eyed vireo	1987-91
Scarlet tanager	1986-91
Species occurring primarily in 8-10 year-old clearcuts:	
Tufted titmouse	1990,91
Willow flycatcher	1990,91

Table A-3. Percent occurrence of 62 bird species observed on the control plots from 1981 to 1991.

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Acadian flycatcher (_Empidonax virescens_)	66.6					100		
Alder flycatcher (_Empidonax traillii_)					33.3	100		
American goldfinch (_Spinus tristis_)		33.3				33.3	33.3	
American redstart (_Setophaga ruticilla_)	33.3	100	66.6	66.6	66.6	66.6	100	100
American woodcock (_Scolopax minor_)					33.3	33.3	33.3	33.3
Blackburnian warbler (_Dendrocia fusca_)		33.3						
Black-billed cuckoo (_Cocyzus americanus_)	33.3	66.6		66.6	33.3	100	33.3	100
Black-capped chickadee (_Parus atricapillus_)	100	100	100	66.7	100	100	100	100
Black-throated green warbler (_Dendroica virens_)					33.3	66.6	33.3	

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Blue-gray gnatcatcher (*Polioptila caeruela*)		66.3				100		
Blue jay (*Cyanocitta cristata*)	100	100	100	100	100	100	100	100
Blue-winged warbler (*Vermivora pinus*)		33.3						
Brown creeper (*Certhia familiaris*)		66.6				66.6		33.3
Brown-headed cowbird (*Molothrus ater*)	100	100	66.6	100	66.6	100	100	100
Cedar waxwing (*Bombycilla cedrorum*)	66.6	33.3	33.3			33.3		33.3
Chestnut-sided warbler (*Dendroica pensylvanica*)	100	100					66.6	
Common crow (*Corvus brachyrhynchos*)								33.3
Common Grackle (*Quiscalus quiscula*)	33.3	66.6	33.3			66.6	33.3	66.6

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Common yellowthroat (<u>Geothlypis trichas</u>)	66.6	66.6					66.6	66.6
Cooper's Hawk (<u>Accipiter cooperii</u>)							33.3	
Downy woodpecker (<u>Picoides vilosus</u>)	33.3			33.3	100	100		100
Eastern bluebird (<u>Sialia sialis</u>)		33.3				33.3		
Eastern phoebe (<u>Sayornis phoebe</u>)	66.6	33.3						
Eastern wood peewee (<u>Contopus virens</u>)	100	100	100	100	100	100	100	100
Golden-winged warbler (<u>Vermivora chrysoptera</u>)	33.3	66.6				33.3	66.6	33.3
Goshawk (<u>Accipiter gentilis</u>)	33.3	33.3					33.3	
Gray catbird (<u>Dumetella carolinesis</u>)	33.3	33.3				33.3	33.3	

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Great-crested flycatcher (*Myiarchus crinitus*)	66.6	66.6	100	100	100	100	100	100
Hairy woodpecker (*Dendrocopos villosus*)	66.6	33.3	100	100	100	100	33.3	66.6
House wren (*Troglodytes aedon*)	100	100	33.3	66.6	66.6	66.6	100	66.6
Indigo bunting (*Passerina cyanea*)						33.3		33.3
Least flycatcher (*Epidonax minimus*)	100	100	33.3	100	100	100	33.3	66.6
Mourning dove (*Zenaidura macroura*)			33.3	33.3				
Mourning warbler (*Oporornis philadelphia*)	100	66.6	33.3	33.3	66.6	100		
Nashville warbler (*Vermivora ruficapilla*)	100	66.6	33.3	33.3	66.6	100		
Northern cardinal (*Cardinalis cardinalis*)					100	100	66.6	66.6

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Northern flicker (*Colaptes auratus*)	66.6	100	33.3	33.3	66.6	100	66.6	
Northern oriole (*Icterus galbula*)	100	100	100	100	100	100	100	33.3
Northern waterthrush (*Seiurus noveboracensis*)		66.6	66.6	100	100	100	100	100
Ovenbird (*Seiurus aurocapillus*)	100	100	100	100	100	100	100	100
Red-eyed vireo (*Vireo olivaceus*)	100	100	100	100	100	100	100	100
Red-headed woodpecker (*Melanerpes erythrocephalus*)				33.3		33.3		
Red-winged blackbird (*Agelaius phoeniceus*)	66.6	100	33.3		33.3	66.6		
Rose-breasted grosbeak (*Pheuticus ludovicianus*)	100	100	66.6	100	100	100	100	100
Ruffed grouse (*Bonasa umbellus*)						100	100	100

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Rufous-sided towhee (*Pipilo erythrophthalmus*)	100	66.6	33.3		33.3	33.3		
Scarlet tanager (*Piranga olivacea*)		100		66.6	100	100	100	100
Song sparrow (*Melospiza melodia*)	66.6	33.3				33.3	100	33.3
Starling (*Sturnus vulgaris*)	66.6							
Tennessee warbler (*Vermivora peregrina*)		100						
Tree sparrow (*Spizella arborea*)		0.33						
Tree swallow (*Iridoprocne bicolor*)				66.6	33.3	33.3		
Veery (*Catharus fuscescens*)	100	100	100	100	100	100	100	100
Warbling vireo (*Vireo gilbus*)								33.3

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Whip-por-will (*Caprimulgus vociferus*)						33.3		
White-breasted nuthatch (*Sitta carolinensis*)	66.6	100	100	100	100	100	100	100
Wood thrush (*Hilochichla mustelina*)	66.6	100	100	66.6	100	100	100	100
Yellow-bellied sapsucker (*Sphyrapicus varius*)						100		
Yellow billed cuckoo (*Coccyzus americanus*)	33.3	33.3	33.3	66.6	66.6	66.6		
Yellow-breasted chat (*Icteria virens*)						33.3		
Yellow-throated vireo (*Vireo flavifrons*)				100	66.6	100	66.6	
Yellow warbler (*Dendroica petechia*)		0.33						

Table A-3. Percent occurrence of 76 bird species observed on the treatment plots from 1981 to 1991.

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Acadian flycatcher (Empidonax virescens)						100		
Alder flycatcher (Empidonax traillii)			66.6	100	100	100		
American goldfinch (Spinus tristis)		33.3	100	100	100	100	100	100
American redstart (Setophaga ruticilla)	33.3		100	100	100	100	33.3	
American robin (Turdus migratorius)	66.6	100	100	66.6	100	100	33.3	66.6
American woodcock (Scolopax minor)							100	100
Bay-breasted warbler (Dendrocia castanea)							33.3	
Black-billed cuckoo (Cocyzus americanus)	100		66.6	100	100	100	100	100
Black-capped chickadee (Parus atricapillus)	100		66.6	100	66.6	100	33.3	

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Black-throated blue warbler (*Dendroica caervlescens*)							33.3	
Black-throated green warbler (*Dendroica virens*)						66.6		
Blue-gray gnatcatcher (*Polioptila caeruela*)				33.3				
Blue jay (*Cyanocitta cristata*)	100	100	66.6	100	100	100	100	100
Blue-winged warbler (*Vermivora pinus*)			100	100	100	100	66.6	100
Broad-winged hawk (*Buteo platypterus*)				33.3	66.6			
Brown-headed cowbird (*Molothrus ater*)	66.6	100	100	100	100	100	100	100
Brown thrasher (*Toxostoma rufrum*)				33.3			33.3	
Cedar waxwing (*Bombycilla cedrorum*)	66.6		33.3	66.6	100	33.3	33.3	100

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Chestnut-sided warbler (*Dendroica pensylvanica*)	100	33.3	100	100	100	100	100	66.6
Common crow (*Corvus brachyrhynchos*)	66.6				33.3			
Common Grackle (*Quiscalus quiscula*)	66.6	100		33.3	100	100	33.3	66.6
Common yellowthroat (*Geothlypis trichas*)	66.6	33.3	100	100	100	100	100	100
Conneticutt warbler (*Oporornis agilis*)							33.3	
Dark-eyed junco (*Junco hyemalis*)								100
Downy woodpecker (*Picoides vilosus*)					33.3		66.6	
Eastern bluebird (*Sialia sialis*)		33.3					33.3	33.3
Eastern Kingbird (*Tyrannus tyrannus*)		100		66.6	66.6	33.3		

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Eastern phoebe (*Sayornis phoebe*)	33.3							
Eastern wood peewee (*Contopus virens*)	100	66.6	66.6					
Field sparrow (*Spizella pusilla*)		33.3	100	66.6	66.6	100	66.6	33.3
Golden-winged warbler (*Vermivora chrysoptera*)	100	100	100	100	100	100	100	100
Gray catbird (*Dumetella carolinesis*)	33.3	100	100	100	100	100	100	100
Great-crested flycatcher (*Myiarchus crinitus*)	66.6	100	100	100	100	100	33.3	33.3
Hairy woodpecker (*Dendrocopos villosus*)	66.6	66.6		33.3	33.3			33.3
House wren (*Troglodytes aedon*)	100		100		100		33.3	66.6
Indigo bunting (*Passerina cyanea*)	33.3	66.6	66.6	33.3	100	100	33.3	33.3

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Killdeer (*Charadrius vociferus*)		33.3						
Least flycatcher (*Epidonax minimus*)	100	33.3	100	33.3	100	100	100	
Magnolia warbler (*Dendroica magnolia*)				33.3	33.3			
Mourning dove (*Zenaidura macroura*)		33.3		33.3	66.6		33.3	33.3
Mourning warbler (*Oporornis philadelphia*)	100	66.6	100	100	100	66.6		
Nashville warbler (*Vermivora ruficapilla*)					33.3		66.6	33.3
Northern cardinal (*Cardinalis cardinalis*)		33.3		33.3	66.6	100		
Northern flicker (*Colaptes auratus*)	33.3	66.6	66.6	100	66.6	100	100	66.6
Northern harrier (*Circus cyaneus*)				66.6				

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Northern oriole (_Icterus galbula_)	100	100	100	100	100	100	100	100
Northern waterthrush (_Seiurus noveboracensis_)							33.3	
Olivesided flycatcher (_Contopus borealis_)				33.3			33.3	
Ovenbird (_Seiurus aurocapillus_)	100	33.3	33.3					
Red-eyed vireo (_Vireo olivaceus_)	100		66.6	33.3	100	100		
Red-headed woodpecker (_Melanerpes erythrocephalus_)	33.3							
Red-tailed hawk (_Buteo jamaicensis_)						33.3		
Red-winged blackbird (_Agelaius phoeniceus_)	33.3	100	66.6	66.6	66.6	100	33.3	66.6
Rose-breasted grosbeak (_Pheuticus ludovicianus_)	100	100	100	100	100	100	100	100

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Ruby-throated hummingbird (_Archilochus colubris_)				66.6				33.3
Ruffed grouse (_Bonasa umbellus_)					66.6	100	100	100
Rufous-sided towhee (_Pipilo erythrophthalmus_)	66.6	100	100	100	100	100	100	100
Rusty blackbird (_Euphagus carolinus_)	33.3							
Scarlet tanager (_Piranga olivacea_)	66.6	33.3		66.6	33.3			
Song sparrow (_Melospiza melodia_)	100	100	100	100	100	100	100	100
Starling (_Sturnus vulgaris_)	33.3	33.3						
Tennessee warbler (_Vermivora peregrina_)				33.3				
Tree sparrow (_Spizella arborea_)	66.6							

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Tree swallow (*Iridoprocne bicolor*)			33.3				33.3	33.3
Tufted titmouse (*Parus bicolor*)							33.3	66.6
Turkey vulture (*Cathartes aura*)				33.3	33.3	33.3		33.3
Veery (*Catharus fuscescens*)	100	100	66.6				33.3	33.3
Warbling vireo (*Vireo gilbus*)			66.6	33.3	33.3		33.3	
Whip-por-will (*Caprimulgus vociferus*)			33.3					
White-breasted nuthatch (*Sitta carolinensis*)	33.3						33.3	66.6
White-throated sparrow (*Zonotrichia albicollis*)				100		66.6	66.6	66.6
Willow flycatcher (*Epidonax minimus*)							100	100

Table A-3. (cont.'d)

Bird Species	Year							
	1981	1982	1986	1987	1988	1989	1990	1991
Wood thrush (<u>Hilochichla</u> <u>mustelina</u>)	100		66.6		100			
Yellow-bellied flycatcher (<u>Epidonax</u> <u>flaviventris</u>)							33.3	
Yellow billed cuckoo (<u>Coccyzus</u> <u>americanus</u>)	33.3			100	100	100	100	100
Yellow warbler (<u>Dendroica</u> <u>petechia</u>)	33.3		100	100	100	100	100	100

Table A-4. Bird species assigned to foraging and nesting strategy guilds for guild-habitat association analysis for study plots in Midland County, Michigan.

FORAGING GUILDS

Foliage Foragers

American redstart
Black-billed cuckoo
Black-capped chickadee
Blue-winged warbler
Chestnut-sided warbler
Common yellowthroat
Golden-winged warbler
House wren
Indigo bunting
Nashville warbler
Northern oriole
Red-eyed vireo
Red-winged blackbird
Rose-breasted grosbeak
Warbling vireo
Yellow-billed cuckoo
Yellow-throated vireo
Eastern kingbird
Yellow warbler

Tree (bark) Gleaners

Brown creeper
Red-headed woodpecker
White-breasted nuthatch

Tree Drillers

Downy woodpecker
Hairy woodpecker

Ground Foragers

American robin
Brown thrasher
Common flicker
Dark-eyed junco
Field sparrow
Gray catbird
Mourning warbler
Northern cardinal
Northern waterthrush
Ovenbird
Rufous-sided towhee
Song sparrow
Veery
White-throated sparrow
Wood thrush

Flycatchers

Alder flycatcher
Blue-gray gnatcatcher
Eastern kingbird
Eastern phoebe
Eastern wood peewee
Great-crested flycatcher
Least flycatcher
Tree swallow
Willow flycatcher

NESTING GUILDS

Primary Cavity Nesters

Black-capped chickadee
Common flicker
Downy woodpecker
Hairy woodpecker
Red-headed woodpecker
White-breasted nuthatch

Secondary Cavity Nesters

Brown creeper
Great-crested flycatcher
House wren
Tree swallow

Table A-4. (cont.'d)

Hardwood Tree Nesters	Ground Nesters
American redstart	Blue-winged warbler
American robin	Common yellowthroat
Black-billed cuckoo	Dark-eyed junco
Blue-gray gnatcatcher	Eastern phoebe
Eastern kingbird	Field sparrow
Eastern wood peewee	Golden-winged warbler
Least flycatcher	Indigo bunting
Northern Oriole	Mourning warbler
Red-eyed vireo	Nashville warbler
Rose-breasted grosbeak	Northern waterthrush
Scarlet tanager	Ovenbird
Warbling vireo	Rufous-sided towhee
Wood thrush	Veery
Yellow-billed cuckoo	
Shrub / Sapling Nesters	
Alder flycatcher	
Brown thrasher	
Chestnut-sided warbler	
Gray catbird	
Northern cardinal	
Red-winged blackbird	
Song sparrow	
Willow flycatcher	
Yellow warbler	

Table A-5. Ruffed grouse drumming log use (illustrated in Figure 4) from 1981-1991, Midland County, Michigan.

Log #	Years of Utilization	Log #	Years of Utilization
1	1991	20	1988
2	1991	21	1986
3	1987-91	22	1989-91
4	1988-90	23	1984,91
5	1985,86	24	1981
6	1981,84,85,87-90	25	1983
7	1982-85,87,90	26	1991
8	1986	27	1984,87
9	1981	28	1987,89
10	1985	29	1983
11	1985-89,91	30	1984
12	1981-82,84-85,91	31	1989-91
13	1989	32	1981,85,91
14	1983	33	1981
15	1982-91	34	1987
16	1985	35	1990
17	1982	36	1989-90
18	1981-82	37	1987-90
19	1987-88	38	1982,87,90